MINISTRY OF EDUCATION AND SCIENCE OF THE REPUBLIC OF KAZAKHSTAN

СӘТБАЕВ УНИВЕРСИТЕТІ SATBAYEV UNIVERSITY

School of Industrial Automation and Digitalization

Department of Industrial Engineering

Mamyrbekov M. M.

3D MODELING OF BALL MILL DRIVE

DIPLOMA PROJECT

5B071200 – Mechanical Engineering

Almaty 2020

MINISTRY OF EDUCATION AND SCIENCE OF THE REPUBLIC OF KAZAKHSTAN

School of Industrial Automation and Digitalization

Department of Industrial Engineering

APPROVED FOR DEFENSE

Head of the Industrial

Engineering Department, PhD

Arymbekov B.S.

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DIPLOMA PROJECT

Topic: “**3D Modeling of Ball Mill Drive**”

5B071200 – Mechanical Engineering

Performed by: Mamyrbekov M. M.

Candidate of Sciences
Docent, associate professor
_______Isametova M.E
___________2020

Almaty 2020

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ДАТА ОТЧЕТА: 2020-05-16 20:43:31

НАЗВАНИЕ:
3D Modeling of ball mill drive

АВТОР:
Мамырбеков Мирас Мамырбекұлы

НАУЧНЫЙ РУКОВОДИТЕЛЬ:
Мадина Исаметова

Показать детали:

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Обратите внимание!Высокие значения коэффициентов не означают плагиат. Отчет должен быть проанализирован экспертом.

2,03% КП1	0,62% КП2	0,94% КЦ
25 Длина фразы для коэффициента подобия 2	4041 Количество слов	24145 Количество символов

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В этом разделе вы найдете информацию, касающуюся манипуляций в тексте, с целью изменить результаты проверки. Для того, кто оценивает работу на бумажном носителе или в электронном формате, манипуляции могут быть невидимы (может быть также целенаправленное вписывание ошибок). Следует оценить, являются ли изменения преднамеренными или нет.

Замена букв	53	показать в тексте
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Микропробелы	0	показать в тексте
Белые знаки	0	показать в тексте

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Просмотрите список и проанализируйте, в особенности, те фрагменты, которые превышают КП №2 (выделенные жирным шрифтом). Используйте ссылку «Обозначить фрагмент» и посмотрите, являются ли выделенные фрагменты повтояющимися короткими фразами, разбросанными в документе (совпадающие сходства), многочисленными короткими фразами расположенные рядом друг с другом (парафразирование) или обширными фрагментами без указания источника ("криптоцитаты").

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MINISTRY OF EDUCATION AND SCIENCE OF THE REPUBLIC OF KAZAKHSTAN

School of Industrial Automation and Digitalization

Department of Industrial Engineering

5B071200 – Mechanical Engineering

CONFIRM

Head of the Industrial

Engineering Department, PhD

Arymbekov B.S.

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TASK

for completing the diploma project

For student: Mamyrbekov M. M.
Topic: "**3D Modeling of Ball Mill Drive**"
Approved *by the order of university rector №762-b from "27" January 2020*
Deadline for completion the work *"24" May 2020*
Initial data for the diploma project: computer modelling of ball mill drive
Summary of the diploma project:

a) *Description and operation principle of ball mills*
b) *Modeling a Ball Mill Drive*
c) *Constructing of titanium-niobium powder for additive technologies*
d) *Study of the shaft for displacement, stress and deformation*

List of graphic material: *presented 20 slides of presentation of the diploma project*
Recommended main literature:

a) Baisogolov V. G. Mechanical and transport equipment of factories of the refractory industry. - M: Metallurgy, 1984. – 294p.

b) Ilyevich A. P. Machines and equipment for factories for the production of ceramics and refractories. - M: Machine building,1968. – 355p.
c) Sapozhnikov, M. Y. Mechanical equipment of enterprises of building materials, products and structures.
d) Leonova L. M., Chigrik N. N., Tataurova V. P. Gears. Elements of calculation and construction: Guidelines.

THE SCHEDULE

For the diploma work preparation

Name of sections, list of issues being developed	Submission deadlines to the scientific adviser	Notes
Theoretical part	10.03.2020	Task completed
Technical part	23.03.2020	Task completed
Calculation part	8.04.2020	Task completed
Modeling part	15.04.2020	Task completed

Signatures

Of consultants and standard controller for the completed diploma work, indicating the relevant sections of the work (project).

The section titles	Consultant name (academic degree, title)	Date	Signature
Theoretical part	Docent, Isametova M.E	10.03.2020	
Technical part	Docent, Isametova M.E	23.03.2020	
Calculation part	Docent, Isametova M.E	8.04.2020	
Modeling part	Docent, Isametova M.E	15.04.2020	
Normcontrol	Docent, Isametova M.E	22.05.2020	

Scientific adviser ________________ Docent, Isametova M.E
Signature

The task was completed by student: ___________ Mamyrbekov M. M.
Signature

Date: “22” May 2020

ANNOTATION

Diploma thesis on "3D Ball Mill Drive Modeling".

In this diploma thesis the issues of 3D modeling of ball mill drive are considered.

In conducting the description of ball mills, as they are divided by drum design, as well as on the principle of operation and type of lining.

In the first chapter of the work, general information about ball mills and their devices, as well as their operating principles, was given. In addition, the method of obtaining composite titanium - niobium powder for additive technologies was studied.

Drawings 2D have been designed in program "KOMPAS-3D".

3D models of ball mill drive were designed in the program "SolidWorks". Initially, all components were made separately, and then the assembly of the gearbox was made.

Calculation of shaft on tension, on moving and on deformation have been calculated by the program "SolidWorks". According to the calculations, we can conclude that tension and deformation appear at the fixing points. Since the forces are not so great, they will not affect the subsequent operation of the shaft. As for the displacement calculation, we can conclude that displacement occurs at the tooth meshing points.

АҢДАТПА

Дипломдық жұмыс тақырыбы: "Шарлы диірмен жетегін 3D модельдеу".

Бұл дипломдық жұмыста шарлы диірмен жетегін 3D модельдеу мәселелері қарастырылды.

Кіріспеде сонымен қатар, жұмыс істеу принципі бойынша және футеровканың түрі бойынша бөлінуі қарастырылды.

Жұмыстың бірінші бөлімінде шарлы диірмендер және олардың құрылғылары туралы жалпы ақпарат берілді, сондай-ақ олардың жұмыс принциптері баяндалды. Және де, аддитивті технологиялар үшін композитті титан – ниобий ұнтағын алу әдісі зерттелді.

2D сызбалар "КОМПАС-3D" бағдарламасында жобаланған.

Шар диірмені жетегінің 3D моделі "SolidWorks" бағдарламасында құрастырылған. Бастапқыда барлық компоненттер жеке жасалып, содан кейін толық редуктор құрастырылды.

Біліктің кернеулікке, жылжуға және деформацияға есептелуі "SolidWorks" бағдарламасының көмегімен есептелді. Есептерге сәйкес, біз кернеу мен деформация бекіту орындарында пайда болады деп қорытынды жасай аламыз. Әсер ету күші үлкен емес болғандықтан, сол себепті олар валдың келесі жұмысына әсер етпейді. Орын ауыстырудың есептеуіне келетін болсақ, орын ауыстыру тістерді ілу орындарында пайда болады деп қорытынды жасауға болады.

АННОТАЦИЯ

Дипломная работа на тему «3D моделирование привода шаровой мельницы»

В данной дипломной работе рассмотрены вопросы по 3D моделированию привода шаровой мельницы.

В ведении дается описание шаровых мельниц, как они делятся по конструкции барабан, а так же по принципу работы и по виду футеровки.

В первой главе работы была изложена общая информация о шаровых мельницах и их устройствах, а так же их принципы работы. Вдобавок, был изучен способ получения композитного титано – ниобиевого порошка для аддитивных технологий.

Чертежи 2D были спроектированы в программе «КОМПАС-3D».

3D модели привода шаровой мельницы были сконструированы в программе «SolidWorks». Изначально были сделаны все компоненты по отдельности, а потом была сделана сборка редуктора.

Вычисление вала на напряженность, на перемещение и на деформацию были вычислены с помощью программы «SolidWorks». Согласно расчетам, мы можем сделать заключение, что напряженность и деформирование появляются в местах крепления. Так как силы воздействия не такие большие, по этой причине они не станут воздействовать на последующую работу вала. Что касается расчета на перемещение, можно сделать заключение, что перемещение появляется в местах зацепление зубьев.

CONTENT

INTRODUCTION

Currently, ball mills are in high demand in various industries for grinding solid materials. With this mill, you can get different types of grinding – coarse and powdery.

By changing the speed of rotation of the drum, you can distinguish two main modes of operation: at low speed – cascading, at high speed-waterfall.

Ball mills are divided according to their structural features:

1) cylindrical single-chamber and multi-chamber;

2) conical;

- according to the types of work:

- 1) periodic action; 2) permanent action-with peripheral unloading and with unloading through a hollow axle;

- by type of lining and types of grinding media:

- 1) with non-metallic lining and metal grinding bodies;

- 2) with metal lining and metal grinding bodies-spheres, with small cylinders or rods;

- by transmission specifics:

- 1) with a gear drive;

- 2) with main drive.

In the non-stop position, the mill can operate in open or closed cycles. Different types of material can be crushed, both wet and dry. [1].

1 General information about ball mills

1.1 The device of the ball mill

The ball mill is a drum with an empty inside, closed with loading and unloading end caps, filled with bodies that rotates around its axis. The ball mill drum, Figure 1, is a steel cylinder with a void, lined inside with armored lining plates, protecting it from the impact and rubbing effects of balls, and grinding material. The shape of the lining of the mill drum has a noticeable effect on its operation. Lining drums of ball mills operating on large source material, have ribs. For mills that work on small material, lining with small ribs or very smooth ones are used. The height, relative position and shape of the ribs determine the adhesion of the grinding medium to the drum and the results of the mill. Therefore, it is important that when the lining is worn, the nature of its surface remains unchanged [1].

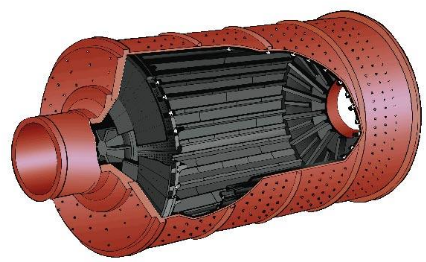


Figure 1 - Ball mill drum [1]

Depending on the method of unloading the crushed product, there are mills with central unloading and unloading through a grate. In mills with central discharge, the crushed product is removed by free discharge through a hollow discharge trunnion. For this, it is necessary that the pulp level in the drum be higher than the level of the lower generatrix of the discharge trunnion. Therefore, mills with central discharge are sometimes called drain type mills or mills with a high pulp level. The discharge neck (funnel) has a slightly larger diameter than the loading neck to create a slope and maintain a high level of pulp in the mill [1].

Mills with unloading through a grate have a lifting device, forcibly unloading the crushed product. Therefore, in mills of this type, the pulp level may be lower than the level of the unloading journal. Mills with discharge through the grate are sometimes called mills with forced discharge or mills with a low level of pulp. This type of ball mill has a grill with discharge holes in the discharge end of the drum

loads of crushed material. On the side facing the end discharge cover, the grill has radial lift ribs dividing the space between the grill and the end cover into sector chambers open in the journal. When the drum rotates, the ribs act as an elevator wheel and raise the pulp to the level of the unloading journal. This device allows you to maintain a low level of pulp in the mill and reduces the residence time of the material in it due to a decrease in the volume of pulp. Ball mills are widely used for coarse and fine grinding of materials. The principle of operation of ball mills consists in grinding material by impact and partially abrasion of freely falling grinding media in a rotating drum [1].

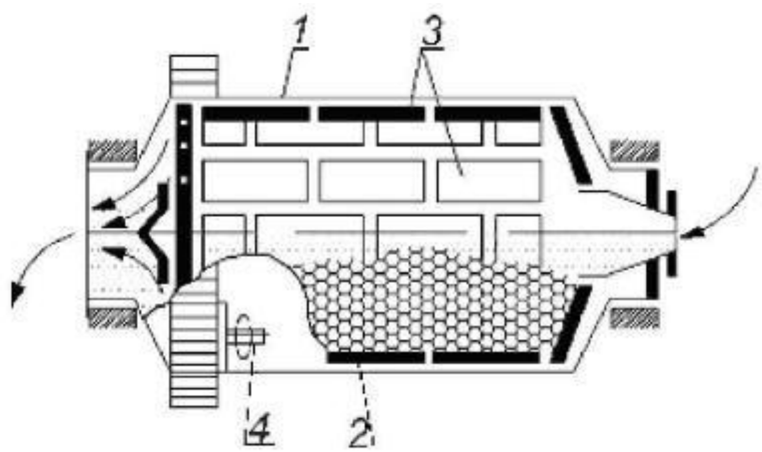
Ball mills are distinguished by a wide variety of designs: with a short and long drum, without partitions and with partitions, with different grinding media, etc.

Advantages of ball mills: obtaining high and constant grinding fineness and its regulation; the possibility of drying the material in the mill itself; simplicity of design; reliability in operation; the possibility of grinding rocks of different hardness.

Disadvantages: significant energy consumption; large mass and size; high starting torque [2].

1.2 The principle of operation of ball mills

A ball mill is a hollow drum rotating around a horizontal axis, which is approximately half filled with crushing balls (percussion elements) [3].



1 - case; 2- grinding bodies; 3 - lining plates; 4 – drive

Figure 2 - Diagram of a drum ball mill [3]

As a result of rotation, the balls, being on the inner surface of the drum, rise, and then under the influence of gravity fall down. Through one of the pins, the source material is constantly supplied. Particles of raw materials are crushed, crushed, erased and stressed. Through another pin, the drum is unloaded.

If the mill is designed for dry grinding, then the processed raw materials are removed using air flow. Air occurs when it is sucked out of the drum. If wet grinding occurs, the material is removed by a stream of water.

With increasing speed, the performance of the drum mill first increases. This is due to the fact that the balls first begin to rise to a great height. However, soon, if the speed continues to increase, the balls begin to “stick” to the inner surface of the drum. In this case, there is a sharp decrease in the productivity of the crushing plant.

Over a period of operation of the mill, its working elements (balls) wear out. In this case, they are simply added to the drum along with the starting material. The maximum load level of the shock elements is 50 mm lower than the circumference of the inlet pipe, Figure 3 [3].

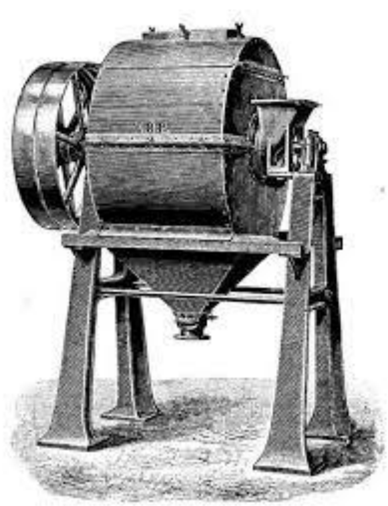


Figure 3 - Ball mill for grinding quartz sand [3]

Let us consider in more detail the design, as well as the scheme for grinding the material in a ball drum mill.

The drum of a modern ball mill is a welded construction made of sheet steel, the inner surface of which is lined with removable armor sheets.

The working parts (grinding bodies) of a ball mill can be balls, rods and other bodies that are raised by a rotating drum to a certain height, and then fall and, thus, work on grinding the material by the impact method. Also, the rotation of the drum body causes the movement of balls, which, moving, abrade the processed bulk material, figure 4 [3].

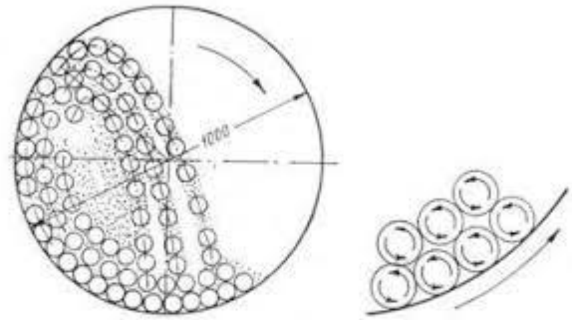


Figure 4 - Movement of balls in a drum ball mill [3]

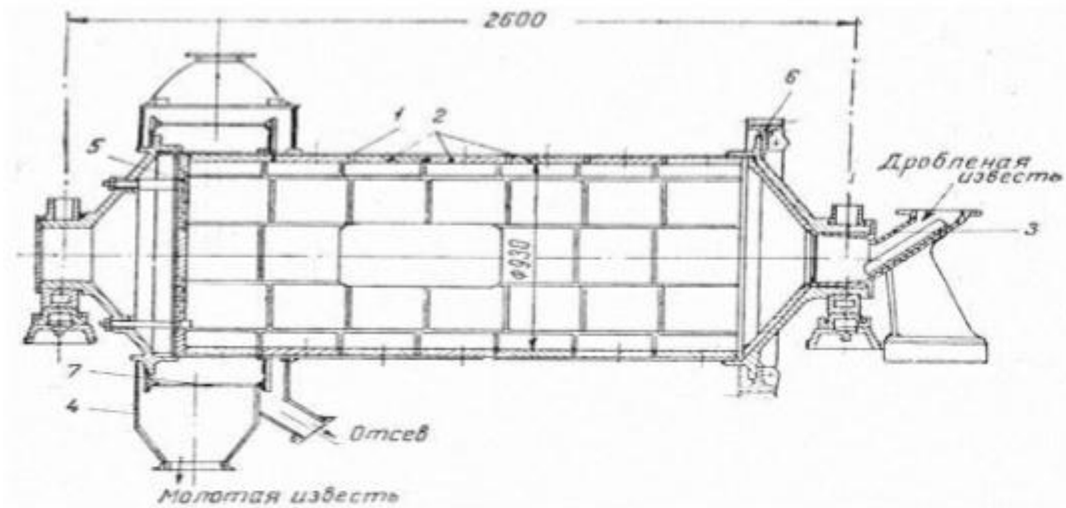
Depending on the design of the ball drum mill, the speed of rotation of the drum, loading the housing with grinding media, the properties of the material being processed, the impact or abrasion effect on the material being processed becomes predominant. So when loading the drum mill body with grinding media for 60% of the drum volume, the abrasive effect on the material being processed is enhanced [4].

In general, by the nature of the destruction of materials, ball drum mills are aggregates for grinding abrasive-impact action. Modern ball drum mills are classified by the following features [8]:

- operation mode: mills of cyclic and continuous action;
- grinding method: mills for dry or wet grinding of materials;
- the method of loading and unloading material: loading and unloading material through hatches, through hollow trunnions, or other types of unloading and loading devices.

Figure 5 shows a diagram of a continuous ball drum mill used for fine grinding of quicklime. Ground quicklime, which was processed by a ball drum mill, was used in the production of silicate and foam silicate products. It is the continuous ball mills of this design that are most often used at enterprises of various industries, where there is a need for large volumes of finely dispersed materials [4].

To intensify the grinding process, it is carried out in a liquid medium, which prevents the spraying of the material. In addition, penetrating into microcracks of particles, the liquid creates a large capillary pressure, contributing to grinding. The liquid also reduces friction both between the grinding bodies and the interparticles of the processed material.



1 - case; 2 - armor plates; 3 - boot heat; 4 - unloading estrus; 5 - perforated wall; 6 - a gear wheel; 7 – sieve

Figure 5 - Diagram of a continuous ball mill company "Zemag-Zeitz" [4]

1.3 A method of obtaining a composite titanium-niobium powder for additive technologies

This mixture of powders can be used in the production of low-modulus alloys based on the titanium-niobium system using selective laser melting methods, which can be used as materials with a low modulus of elasticity for the manufacture of individual implants in medicine.

A known method of producing a composite powder based on the titanium-niobium system, including the placement of titanium powder in an amount of 60 wt. % and niobium powder in an amount of 40 wt. % to the planetary mill. Steel grinding balls are also added to the chamber. A small amount of sodium chloride is added to the chamber to prevent powder from sticking together. Then, to ensure the so-called mechanical welding, the planetary mill rotates at a speed of 250 rpm. The process continues for 40 hours with stops every 15 minutes to cool the chamber. The result is a composite powder of the composition TiNb.

The specified technical result is achieved in that the method of producing a composite titanium-niobium powder for additive technologies involves the mechanical activation of a mixture of titanium and niobium powders with the addition of an anti-agglomerating component, while the mechanical activation of a mixture of titanium and niobium powders is carried out in a shock-friction type planetary ball mill for 10-20 min, with an acceleration of grinding media 40 g, with a ratio of volumes of a mixture of powders and grinding media equal to 1:20, and as an anti-agglomerating component, comfort ethanol.

In this case, a mixture of powders of titanium and niobium is used, with a mass ratio of titanium powder and niobium powder equal to 6: 4.

Ethanol is used in a quantitative ratio to a mixture of titanium and niobium powders equal to 1: 250.

After mechanical activation, the composite powder is packaged in a sealed container filled with argon.

The amount of titanium powder, comprising 60 wt. %, and niobium powder in an amount of 40 wt. % is preferred, since the composite powder can be a raw material for producing a low-modulus TiNb beta alloy, i.e., an alloy of the composition Ti + Nb.

In this case, the ratio of the volume of the mixture and the grinding media 1:20 is chosen. The indicated ratio of the volumes of the mixture and grinding media was selected based on the experiments.

Ethyl alcohol is used as the anti-agglomerating and surfactant component.

The use of ethyl alcohol in the present invention is due to the fact that it easily evaporates and has little effect on the composition of the final product. Ethyl alcohol performs in the present invention not only anti-agglomerating, but also a surfactant function and contributes to the mixing process. After mechanical activation, the composite powder is packaged in a sealed container filled with argon. Gas protects the finished product from oxidation, as the surface of the composite powder is very active.

The final product that implements the proposed method is a mechanocomposite TiNb powder (40 wt.%) With a particle size of 10-50 microns.

Thus, the use of the proposed method provides a composite powder of a given composition with certain properties, with a uniform distribution of titanium and niobium throughout the volume of the particle, which is environmentally friendly due to the absence of foreign substances in the synthesis products, and also reduces the duration of the process.

Figure 6 – titanium-niobium powder

2 Calculation of the ball mill drive

Input data:

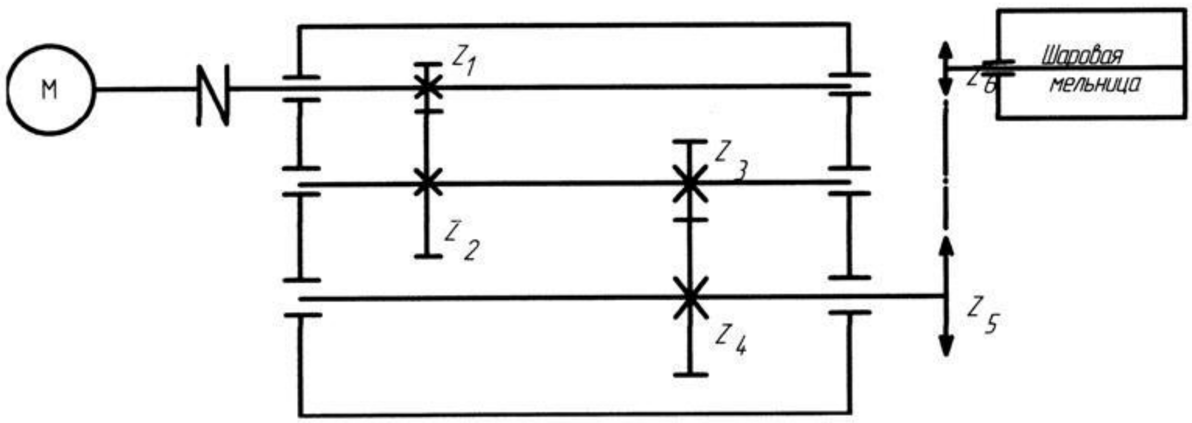
Power on the machine's working shaft…………………………… $N_{w.s..}$= 17,9 kW

Turning speed of the machine working shaft………………………… $n_{w.s.}$= 50 rpm

Electric motor rotation speed……………………………………… n_s = 1500 rpm

Full cycle time = 100%

Kinematics scheme



*Optimise drive selection***.**

Since the machine working shaft's and motor rotational speeds are known, let us determine the approximate total drive ratio.

$U_{dr} = \frac{n_{s.}}{n_{m.w.s.}}$

$U_{dr} = \frac{n_{s.}}{n_{m.w.s.}} = \frac{1500}{50} = 30$

Kinematic calculation of the drive and selection of the electric motor.

Determining the coefficient of efficiency of the drive

$\eta_{dr} = \eta_{r.b.p.} \cdot \eta^2_{o.c.d.} \cdot \eta_{c.g.t.} = 0{,}99^3 \cdot 0{,}97^2 \cdot 0{,}95 = 0{,}87$

Where: η_{dr} - c.o.e. of gearbox,

$\eta_{o.c.d}$ - c.o.e. open chain drive,

$\eta_{r.b.p}$ - c.o.e. rolling bearing pairs,

$\eta_{c.g.t.}$ - c.o.e. closed gear transmission.

Determine the rated power of the electric motor

$N^p_{elec} = \frac{N_{w.s.}}{\eta_{dr}}$

$N^p_{elec} = \frac{N_{w.s.}}{\eta_{dr}} = \frac{17{,}9}{0{,}87} = 20{,}6$ kW

Choose an electric motor

We know that n_c = 1500 rpm, N^p_{elec} = 20,6 kW

By the State standard GOST 19523-81 we choose “4А180М4УЗ” electric motor, N_{elec} = 22 kW, S=2% - normal sliding

Electric motor will work with underload,

20,6—100%

1,4— X% => X = $\frac{1,4\cdot100}{20,6}$ = 6,8% it is admissible as<15%

Determine the asynchronous speed of the motor

$n_{asyn} = n_c\,(1 - \frac{S\%}{100\%})$

$n_{asyn} = n_c\,(1 - \frac{2\%}{100\%})$ = 1470 rpm

Calculation of a two-level reducer.

Calculation of toothed wheels on the first step of the gearbox.

Type of transmission – cylindrical helical.

Material selection: for gears - Steel 45, quenching with high tempering

HB = 269-302

Wheel: HB = 269

Gear: HB = 302

Because the hardness of the surface of the teeth of the wheel is less than the hardness of the surface of the gear, then we calculate the contact stress along the gear

$[\sigma_H]_2 = \sigma_{HO2} \cdot \frac{K_{HL}}{S_H}$

σ_{HO2} - contact endurance limit of the tooth surface with a basic number of stress cycles, MPa

According to the moment M_{III} choose a gearbox (M_{III}= 1972,7 N·m)

2000 — 100 %

27,3 — X % => X = $\frac{27,3\cdot 100}{2000}$ = 1,37 %

We choose “1Ц2У-160” gearbox

3. *Determine the allowable contact voltage*

$\sigma_{HO2} = 2\cdot HB + 70 = 2\cdot 269 + 70 = 608$ MPa

K_{HL}=1- life factor

S_H = 1,2- safety factor

$[\sigma_H]_2 = \frac{608\cdot 1}{1.2}$ = 507 MPa

Determine the center distance

$A = K_a\cdot(u_{1-2} + 1)^3\sqrt{\frac{M_{III} * K_{H\beta}}{\sigma H2\cdot\psi_{a B}\cdot u1-22}}$

K_α = 430, helical gear

$\psi_{ав}$ = 0,315 – the ratio of the width of the rim of the gear relative to the center distance by the GOST 2185- 66

$\psi_{вd} = 0,5 \cdot \psi_{αв}(u_{1-2} + 1) = 0,5 \cdot 0,315(3,55 + 1) = 0,72$

$К_{нβ}$=1,07 – coefficient of uneven load distribution over gear width

$$A = 430 \cdot (3,55 + 1)\sqrt[3]{\frac{456,5 \cdot 1,07}{5072 \cdot 0,315 \cdot 3,552}} = 153 \text{ mm}$$

160 — 100%

7 — X% => $X = \frac{7 \cdot 100\%}{160} = 4,3\%$

Because the underload is less than 15%, then according to the standard we take the value a_{st} = 160 mm

We determine the module

$$m_n = (\frac{0.01}{0.02}) \cdot a_{st} = (\frac{0.01}{0.02}) \cdot 160 = 2,5 \text{ mm}$$

and take m_{st} = 2,5 mm

Determine the total number of teeth

$$Z_\Sigma = (\frac{2 \cdot a}{m_c}) \cdot \cos\beta$$

$$Z_\Sigma = (\frac{2 \cdot 160}{2.5}) \cdot \cos 10° = 126 \text{ pieces.}$$

Determine the number of gear teeth and wheels

$$Z_1 = \frac{Z_\Sigma}{(U_{1-2} + 1)}$$

$$Z_1 = \frac{126}{(3,55 + 1)} = 28 \text{ pieces.}$$

$$Z_2 = Z_\Sigma - Z_1 = 126 - 28 = 98 \text{ pieces.}$$

Specify the gear ratio

$$U_{1-2} = \frac{Z_2}{Z_1} = \frac{98}{28} = 3,53$$

Specify the center distance

$$a_{cd} = 0,5 \cdot m_n (Z_1 + Z_2) \cdot \frac{1}{\cos\beta}$$

We accept, that $\cos\beta = 10°$

$$m_n = m_{ст} \cdot \cos\beta = 2,5 \cdot \cos 10° = 2,46$$

$$a_{cd} = 0,5 \cdot 2,46\,(28 + 98) \cdot \frac{1}{\cos 10°} = 160 \text{ mm}$$

Specify the angle of inclination of the teeth

$$\beta = \arccos(0,5 \cdot m_n \cdot \frac{Z_1 + Z_2}{a_{st}})$$

$$\beta = \arccos(0,5 \cdot 2,46 \cdot \frac{28+98}{160}) = \arccos \cdot 0,98 = 14,4°$$

Determine the calculated contact stress, MPa

$\sigma_{H2}=6160\cdot Z_н \cdot \frac{Z_e}{a_{st}} \cdot \sqrt{\frac{M_{III}\,(u+1)^3\cdot K_{H\alpha}\cdot K_{H\beta}\cdot K_{HV}}{в\cdot u^2}}$

$Z_н$ – the shape coefficient of the mating surfaces of the tooth

We take α=20°

$Z_н = \sqrt{\frac{2\cos\beta}{\sin 2\alpha}} = \sqrt{\frac{2\cdot\cos 14{,}4°}{\sin 2\cdot 20°}} = 1{,}74$

εα – mechanical overlap coefficient

$\varepsilon\alpha = (1{,}88 - 3{,}2(\frac{1}{Z_1} + \frac{1}{Z_2}))\cdot\cos\beta$

$\varepsilon\alpha = (1{,}88 - 3{,}2(\frac{1}{28} + \frac{1}{98}))\cdot\cos 14{,}4 = 1{,}68$

Z_e – coefficient of the total length of the contact lines

$Z_e = \sqrt{\frac{1}{\varepsilon\alpha}} = \sqrt{\frac{1}{1{,}7}} = 0{,}77$

$в_2$ – Width of gear rim, mm

$в = \psi_{ва}\cdot a_{ст}$

$в = 0{,}315\cdot 160 = 50$ mm

$K_{H\alpha} = 1{,}046$ – coefficient taking into account the distribution of load between the teeth

Determine the peripheral speed

$V = \frac{\pi\cdot d2\cdot n2}{60\cdot 1000}$

$V = \frac{3{,}14\cdot 414}{60\cdot 1000} = 5{,}3$ m/s

$d_2 = m_n\cdot Z_2 = 2{,}5\cdot 98 = 245$ mm

$n_1 = 1470$ rpm

$\pi = 3{,}14$

$K_{H\beta} = 1{,}14$ – coefficient of uneven load distribution along the width of the gear

$K_{HV} = 1$ – gearing dynamic load factor

$\sigma_{H2} = \frac{6160\cdot 1{,}68\cdot 0{,}77}{160} \cdot \sqrt{\frac{456{,}5\cdot(3{,}55+1)^3\cdot 1{,}046\cdot 1{,}14\cdot 1}{50\cdot 3{,}55^2}} = 453$ MPa

506— 100%

53 — X% => $X = \frac{100\cdot 53}{506} = 10\%$

Because the overload is less than 15%, then the conditions for calculating contact stresses are satisfied

Determine the allowable bending stress of the gear teeth

$[\sigma]_F = \frac{\sigma_{Fo} \cdot K_{FL} \cdot K_{Fc}}{S_F \cdot Y_S}$

σ_{Fo} – endurance of teeth during bending, corresponding to the base number of stress cycles, MPa

$\sigma_{Fo} = 1,8 \cdot HB$

$\sigma_{Fo1} = 1,8 \cdot 269 = 84,2$ MPa

$\sigma_{Fo2} = 1,8 \cdot 302 = 543,6$ MPa

$K_{FL} = 1$ – life factor

$K_{Fc} = 1,1$– influence factor of two-sided load application

S_F – safety factor

$S_F = S_F^{1} \cdot S_F^{11}$

$S_F^{11} = 1,75$ - the coefficient of instability of the properties of the material of the gear wheel and the responsibility of the gear

$S_F^{1} = 1$ - the coefficient of the method of obtaining the workpiece gear:

$S_F = 1 \cdot 1,75 = 1,75$

$Y_S = 1,035$ - stress gradient coefficient and material sensitivity to stress concentration

$[\sigma]_{F1} = \frac{484,2 \cdot 1 \cdot 1,1 \cdot 1,035}{1,75} = 315$ MPa

$[\sigma]_{F2} = \frac{543,6 \cdot 1 \cdot 1,1 \cdot 1,035}{1,75} = 354$ MPa

Define the estimated bending stress of the teeth of the gears and wheels, MPa

$\sigma_{F2} = \frac{Y_{F2} \cdot Y_\beta \cdot 2000 \cdot M_{III} \cdot K_{F\alpha} \cdot K_{FV}}{B_2 \cdot d_2 \cdot m_{st}}$

Y_F = tooth shape coefficient

$Y_{F1} = 3,6$

$Y_{F2} = 3,8$

$\frac{[\sigma]_{F1}}{Y_{F1}} = \frac{354}{3,6} = 98$ MPa

$\frac{[\sigma]_{F2}}{Y_{F2}} = \frac{315}{3,8} = 83$ MPa

As $\frac{[\sigma]_{F1}}{Y_{F1}} > \frac{[\sigma]_{F2}}{Y_{F2}}$, then we determine the calculated bending stress of the teeth of the wheel

Y_β - tooth inclination coefficient

$Y_\beta = \frac{1-\beta}{140} = \frac{1-14,4}{140} = 0,9$

$K_{F\alpha} = 0,81$ - load distribution coefficient between teeth

$K_{F\beta} = 1,17$ - coefficient of uneven load distribution along the width of the rim

$K_{FV} = 1,15$ - dynamic load factor

$\sigma_{F2} = \frac{3,6 \cdot 0,9 \cdot 2000 \cdot 465,5 \cdot 0,81 \cdot 1,17 \cdot 1,15}{50 \cdot 245 \cdot 2,5} = 105$ MPa

The value of the calculated tooth bending stress should be less than the allowable

$[\sigma]_{F2} > \sigma_{F2}$

$354 > 105$

The calculation condition for bending stress is satisfied.

3 Construction of a 3D model of a ball mill drive

To build a 3D model of a ball mill drive was used SolidWorks program. With this program, every detail has been created.

SolidWorks is a computer program for solid modeling (CAD) and computer aided design (CAE) that runs on Microsoft Windows. SolidWorks was created by Dassault Systèmes. SolidWorks is a solid-state modeler and uses a function-based parametric approach that was originally developed by PTC (Creo / Pro-Engineer) to create models and assemblies [8].

First, the parts will be shown separately, and after that there will be a complete assembly of the gearbox.

Figure 8 shows one of the varieties of the shaft that will be used to assemble the gearbox.

Figure 8 - Shaft 1

Figure 9 shows another type of shaft that will be used to assemble the gearbox.

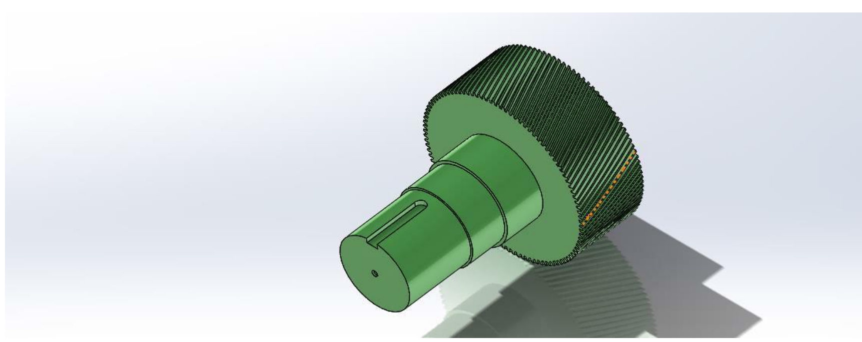


Figure 9 - Shaft 2

Figure 10 shows the bearing that will be inserted onto the shaft.

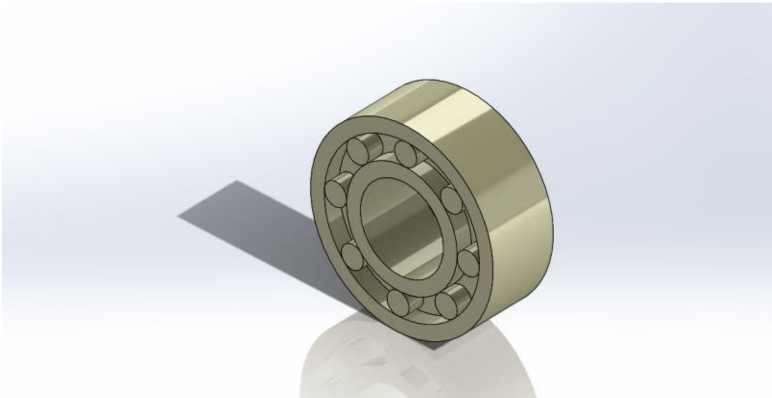


Figure 10 – Bearing

Next, proceed to the assembly of the gearbox. We open all the parts separately and complete the assembly of the gearbox, we took all the bolts and screws from the program itself and selected them according to ISO standards, Figure 11.

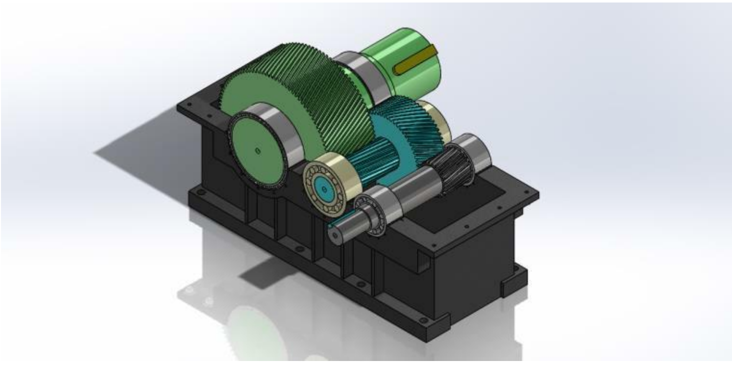


Figure 11 - Assembly of the gearbox without cover

Figure 12 shows the gearbox assembly with cover.

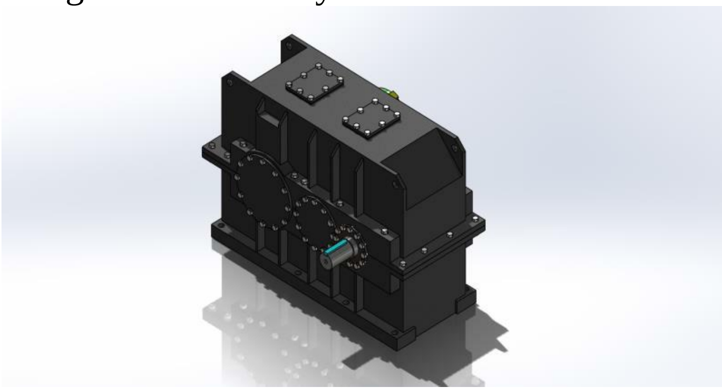


Figure 12 – Reducer

Figures 13 and 14 show a top view and a side view of the gear assembly.

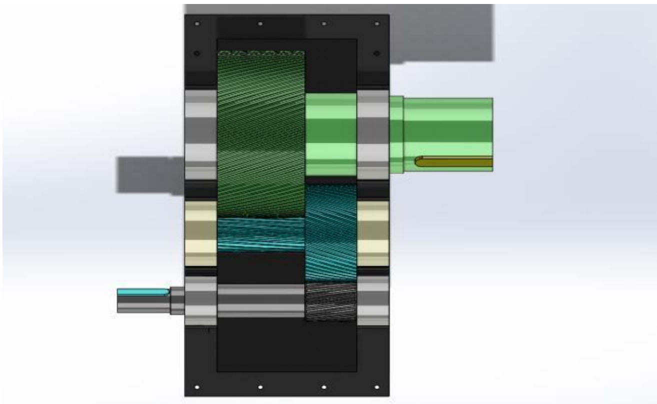


Figure 13 - Top view of the gearbox

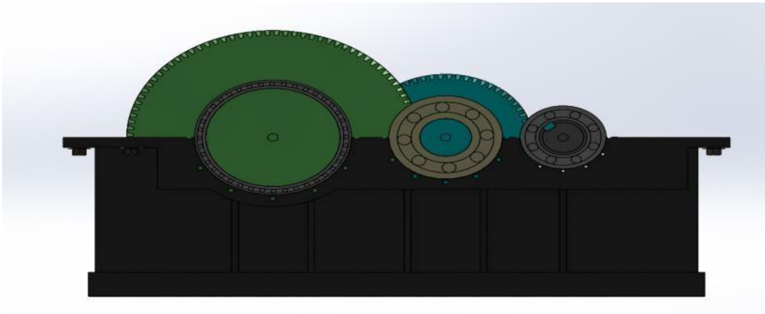


Figure 14 - Left gear view

The final drive model of the ball mill is shown in Figure 15, it shows the gearbox itself, which was modeled in the work above, as well as the electric motor and the part where it will be connected to the ball mill itself for operation.

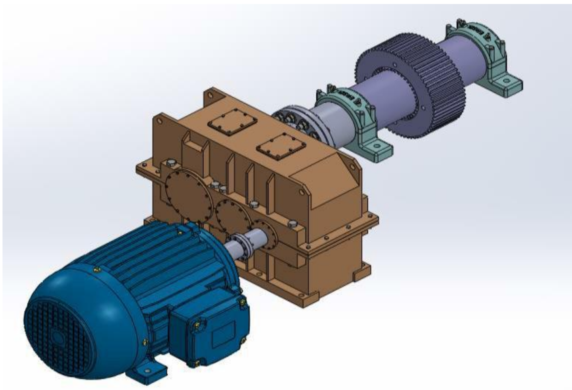


Figure 15 - Model of a ball mill drive

4 Static calculation of the ball mill drive shaft

For the calculation, the «Solidworks» program was used. «Solidworks» software allows you to perform many calculations, including a static analysis of any solid parts. Statistical analysis of the shaft will determine the most susceptible places to stress, displacement, and deformation.

Open the shaft necessary for the calculation in the program, select "Static calculation". The next step is to select the material of the shaft, in my case I chose alloy steel.

Figure 16 - Shaft model with selected material

Next, apply the necessary load on the shaft. We apply torque to the tooth engagement zone.

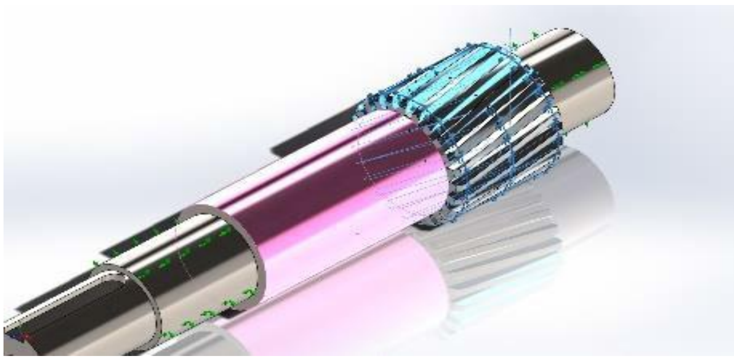


Figure 17 - Shaft with applied torque

After applying the torque, we apply fastening bearings to the engagement zones.

Figure 18 - Shaft with mounts in the area of the bearings

Figure 18 shows a shaft with all installed forces and mounts for a successful calculation.

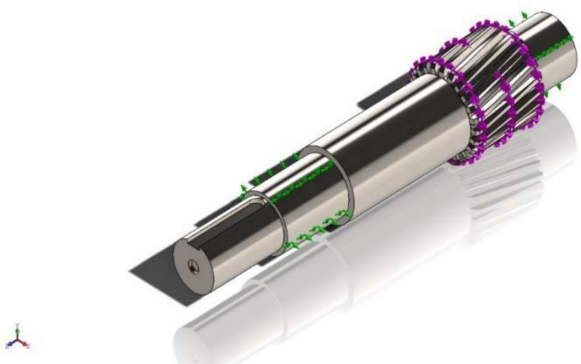


Figure 19 - Shaft with all forces applied

The next step is to install the grid. Click on the “Grid” icon and select the required grid density, Figure 19

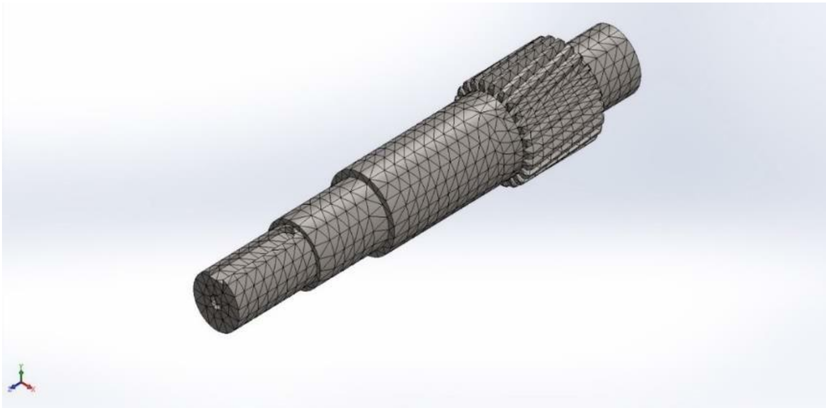


Figure 20 - Shaft with selected mesh density

The final step is the calculation of the shaft itself. Click on the “Run” button and our calculation has started. Ultimately, the result will be given on three types of loads, this is a calculation of stress, displacement and deformation.

Now, for each calculation, a small conclusion can be made.

Figure 20 shows the voltage calculation of the shaft. It can be concluded that small stresses arise in the fastening zones, which means that no changes will occur and will not affect further shaft operation.

Figure 21 - Calculation of the shaft for voltage

The next view is the calculation of the shaft to move. In Figure 21, you can see that the largest displacement occurs in the tooth engagement zone, you can determine how much it is about the schedule.

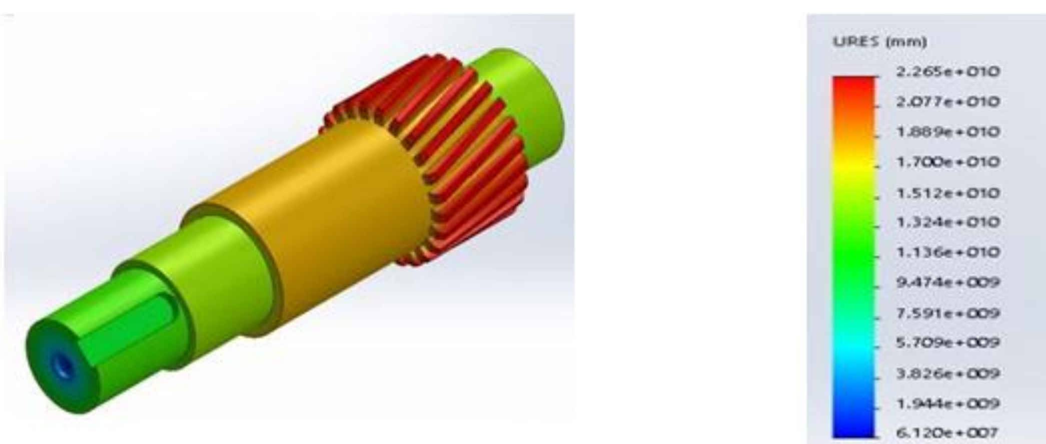


Figure 22 - Calculation of the shaft for displacement

The last calculation is the deformation calculation. From Figure 22, it can be determined that deformation occurs in the zones of fixation. The conclusion is the following: deformation arises small, which means that it will not affect further work.

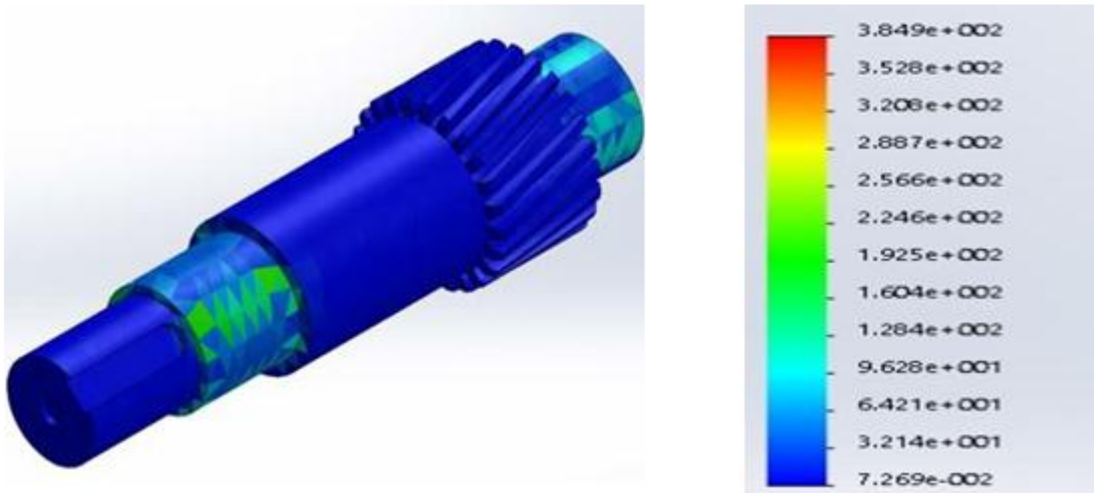


Figure 23 - Calculation of the shaft for deformation

CONCLUSION

So, ball mills are grinding machines for abrasion and impact. Ball drum mills allow rough, medium and fine grinding of solid, bulk materials. Despite the relatively weak impact on the processed material, bulkiness and high energy consumption, ball drum mills are widely used in various fields of production and continue to be used today. The bulk of bulk materials of various origin is grinded precisely on ball drum mills.

You can also draw a small conclusion regarding the shaft calculations for stress, displacement and deformation in the SolidWorks program. When calculating the shaft voltage, in the areas where the bearings are mounted, the voltage appeared insignificant, this is proved by the voltage scale on the side of the shaft. Calculation of displacement, regarding this calculation it can be said that the largest displacements occurred in the tooth engagement zones. And the last calculation, this is the calculation for deformation, from the calculation we can conclude that not a large deformation occurs in the zones of fastening, this can be seen in the graph next to the shaft.

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