STUDY OF REDUCTION GEAR OF MK 2,1X4 WINDING MACHINE IN LONEA MINE

Iosif DUMITRESCU, Mihai Carmelo RIDZI*, Vilhelm ITU ***

Abstract. *The old Shaft winding machine with skip in Lonea Mine has been operational for more than 45 years. Fissures had been noticed at the welding belts of the driving wheel, as well as breaking the extremities of the teeth of the gear wheel. All these required a study of the functioning of the winding machine, and of the reduction gear, respectively. The technical documentation of the winding machine allowed an analysis of the construction and functioning of the transmission of the reduction gear by the gear wheel. Based on the construction parameters and conditions of operation, a verification of the reduction gear transmission has been carried out, for diving gear, shafts, joints with wedge and rolls.*

Key words: *reduction gear, installation, machine, skip, Lonea Mining Plant*

1. Introduction

Underground coal and rock extraction in Lonea Mine is done by the winding machine in the old Shaft with skip , including an MK 2,1x4 winding machine, located in the tower, provided with two 6,5 ton skips.

The daily output in Lonea is 1200 ton and ant dysfunction of the old Shaft with skip winding machine may result in significant production losses and jeopardizing the safety of the seam and of the workers.

Fissures developed along the years at the wheel of the winding machine, fissures occurring both on the wheel hub, and on its spokes, evolving in time in dimension and number.

To reduce the influence of these fissures, at 10-12 months interval repair had been carried out, by welding of the affected areas of the wheel, without demounting it from the operating position.

In order to assess and analyze the causes producing the above mentioned phenomena, and to find practical solutions, to stop the above mentioned solutions in time, Lone Mine applied to the University of Petroşani, Department of Mechanical, Industrial Engineering and Transport to carry out a study referring to the functioning of the winding machine..

2. Presentation of MK 2,1x4 winding machine and exploitation problems

The winding machine itself is located in the tower of the installation old Shaft with skip, Fig. 1 a, the axis of the machine is at level +46,5 m as to the shaft ramp.

* *Assoc.prof.eng. Ph.D, University of Petroşani*
** *Lect.eng. Ph.D, University of Petroşani, Romania*

This is intended to transport coal and rock between the underground loading stations, from level -320 and dump station above ground, level + 21,5 m, with a 342 m route. The forces required to move the skips are transmitted by friction force between the four winding cables and the lining on the friction wheel. To reduce the unbalanced load two compensation cables are used. The winding machine is type MK 2,1x4, and had been purchased from the former USSR and commissioned in the year 1967.

The machine is actuated with two asynchronous motors, with Pn = 2 x 500 kW and 490 rpm nominal rotation, coiled rotor, 6,5 V supply, Fig. 1b. The speed is started and adjusted by coupling and decoupling the rotor resistance steps, and for positioning manoeuvres or low speed movements(for shaft revision) the mechanical maneover brake is used.

In order to buffer the shocks transmitted to the main reduction gear, at the starting and stopping of the driving wheel, it is mounted on two packages of support springs, and it is fixed on the foundation by two buffers. The reduction gear has two steps, with two inlets and one outlet, having transmission ratio 6.

The shaft of the driving wheel is fixed to the main shaft of the reduction gear by a rigid coupling with bolts. Fig. 1 b shows: 1 –500 kW electric motor; 2 – toothed coupling; 3 –cylindrical reduction gear with two steps; 4 –rigid coupling with bolts; 5 – multi-cable driving wheel with 2,1 m diameter; 6 – package with four springs; 7 – buffer; 8 – winding cables.

The breaking of the teeth of the gear wheel of the reduction gear in the extreme areas of the teeth, having before the break a significant wear by contact fatigue , Fig. 2 a. The deterioration phenomenon of the side of the teeth depend on very numerous factors, such as: the material of the geared wheels, dimension and geometric and

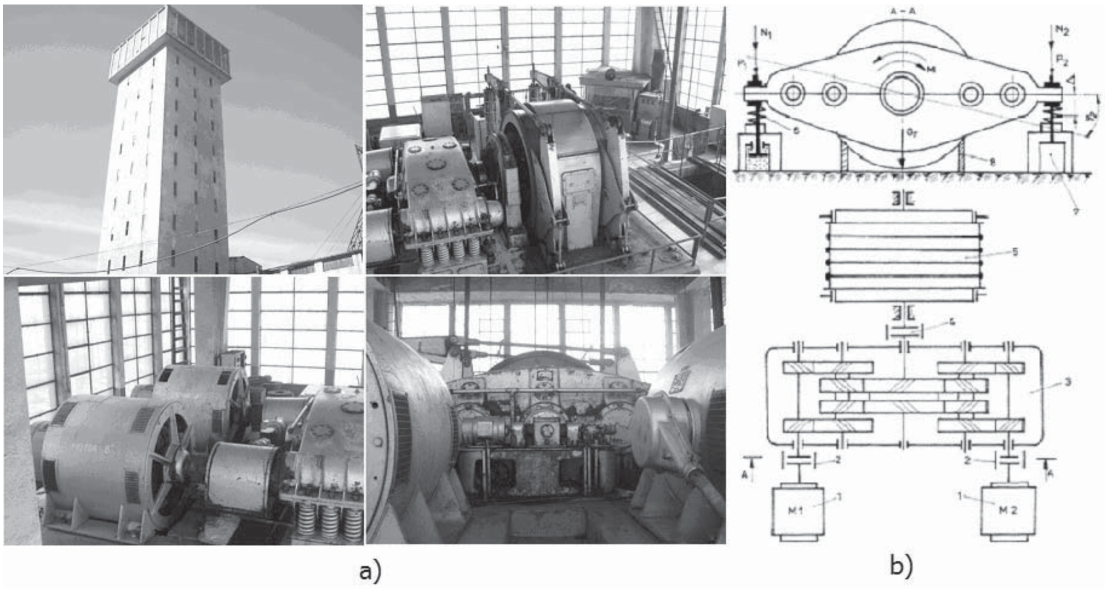


Fig. 1. *MK 2,1x4 winding machine in old Shaft with skip and kinematic diagram*

kinematic elements of the teeth; characteristics of the side area; mechanical strain; greasing and grease quality.

In order to analyze the influence of vibrations on the reduction gear and driving wheel as well, Fig. 2b shows the buffer of the Lonea Mine winding machine, and Fig. 2c for Livezeni Mine, which was mounted four years later, in 1971. It is noticed that the two buffers have different constructions and fixing methods between the reduction gear and the foundation, one by two articulations, and the other rigid, therefore having different functioning and buffering ways. The Lonea one has larger clearance at the articulations, due to the holes for the bolts becoming oval, therefore larger shocks are transmitted to the driving wheel ar starting and stopping.

All these problems occurred in the exploitation of the winding machine, leading to the decrease of safety in its functioning, are caused by the design, construction, and especially the exploitation of the winding machine. If the causes of destruction of the teeth of the machine reduction gear are not established, the coal transport flow might be stopped.

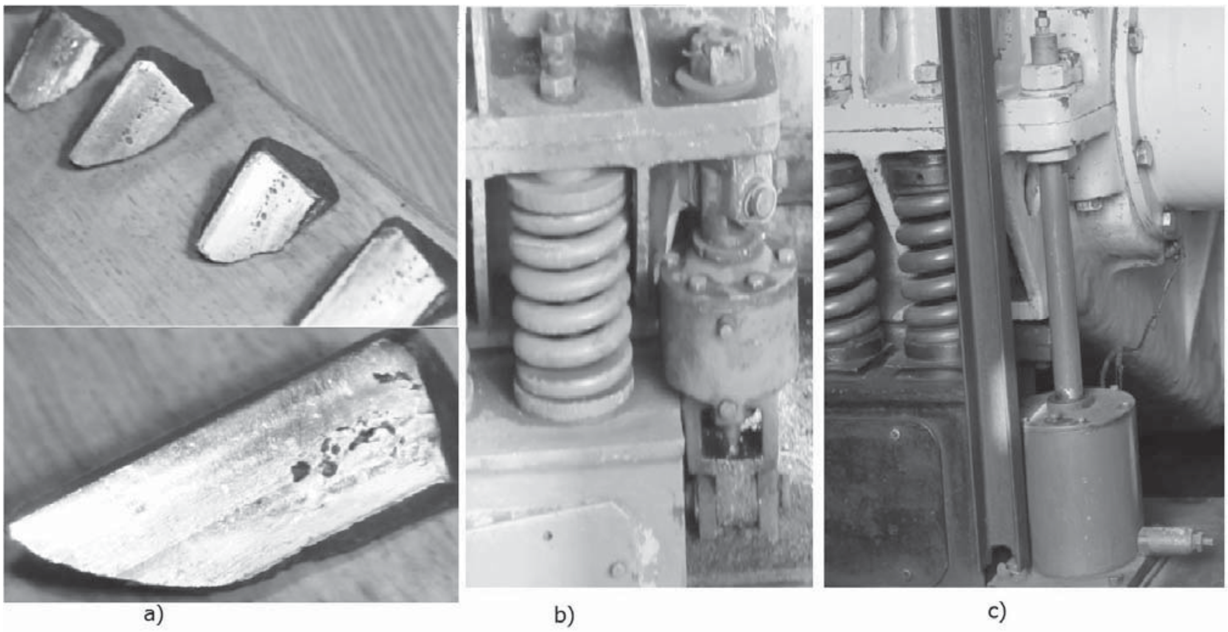


Fig. 2. *Buffer types of winding machines in Lonea and Livezeni Mines*

3. Transmission construction and functioning of MK 2,1x4 machine reduction gear

Based on the technical documentation of MK2,1x4 winding machine, and on the kinematic diagram in Fig. 1b. a 3D model of the reduction gear transmission has been done, where: 1 – inlet shaft; 2 – intermediary shaft; 3 –outlet shaft. The four gears of the reduction carries out the power transmission from the two 500 kW electric motors to the coupling with bolts of the driving wheel. Due to the very large power transmitted. The gears on the two flows have V shaped teeth.

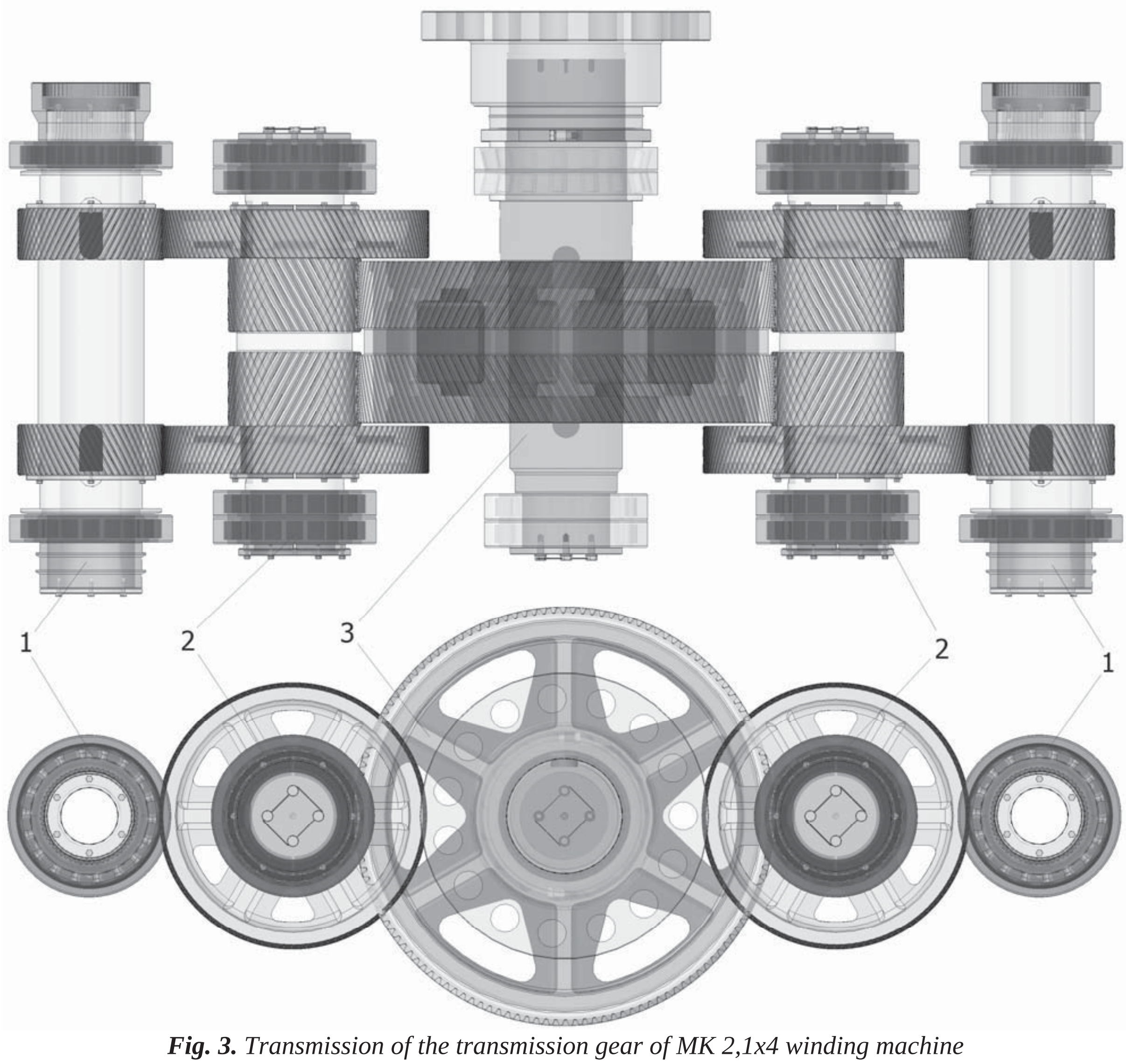


Fig. 3. *Transmission of the transmission gear of MK 2,1x4 winding machine*

Fig. 4 shows the constructive solution of the inlet shaft, made up of: 1 – semi-coupling stopper; 2 – semi-coupling; 3 – radiant bearing with cylindrical NU 252 balls; 4 – greasing sealing disk; 5 – semi-rings to block gear wheel; 6 - 70x36 wedge; 7 – z=60 gear wheel; m=6 right; 8 – tubular shaft; 9 – gear wheel; z=61, m=6 left; 10 - clearance ring with sealing nervures; 11 – stopping ring.

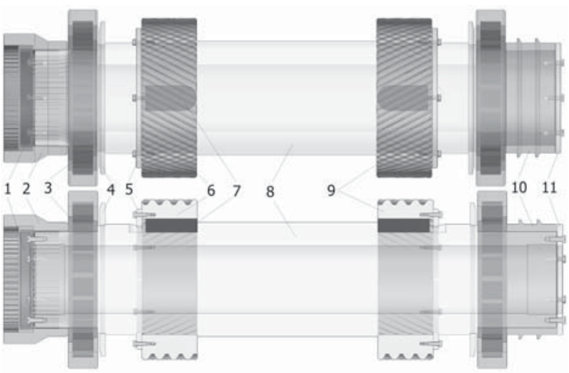


Fig. 4. *Construction of the inlet shaft*

Transmission of the rotation movement from the electric motor to the inlet shaft to the reduction gear is dome by a rod of at least 2500 mm length, having at the ends two semi-couplings with exterior teeth. This rod allows suspending the reduction gear on two packages of four helical compression springs, with buffering role of the oscillations occurred at the starting and the stopping of the electric motors.

Fig. 5 shows the constructive solution of the intermediary shaft, where: 1 – bearing fixing cover; 2 – NU 252 cylindrical balls radial bearing; 3 – gear shaft z = 41, m = 8; 4 – semi-rings to block the gear wheel; 5 – gear wheel z = 113, m = 6 left;6 – up to 70x36; 7 – gear wheel z = 113, m = 6 right; 8 – semi-rings to block bearings; 9 – support ring for the blocking semi-rings. The gear shaft z = 41, m = 8 has the teeth inclined to the left and to the right at the same angle, which annuls axial forces in the two gears through the body of the shaft. Similarly, the gear wheels, marks 5 and 7, annul axial forces through the shaft with the help of the inside sipport shoulder and semi-rings, mark 4, on the outside. Blocking is required in both senses because the reduction gear operates under load at the reversible rotation of the driving wheel.

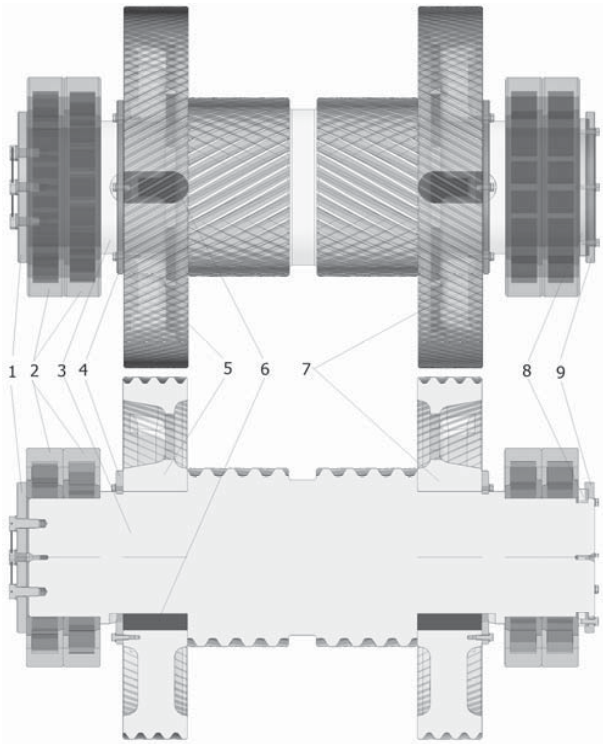


Fig. 5. *Construction of the intermediary shaft*

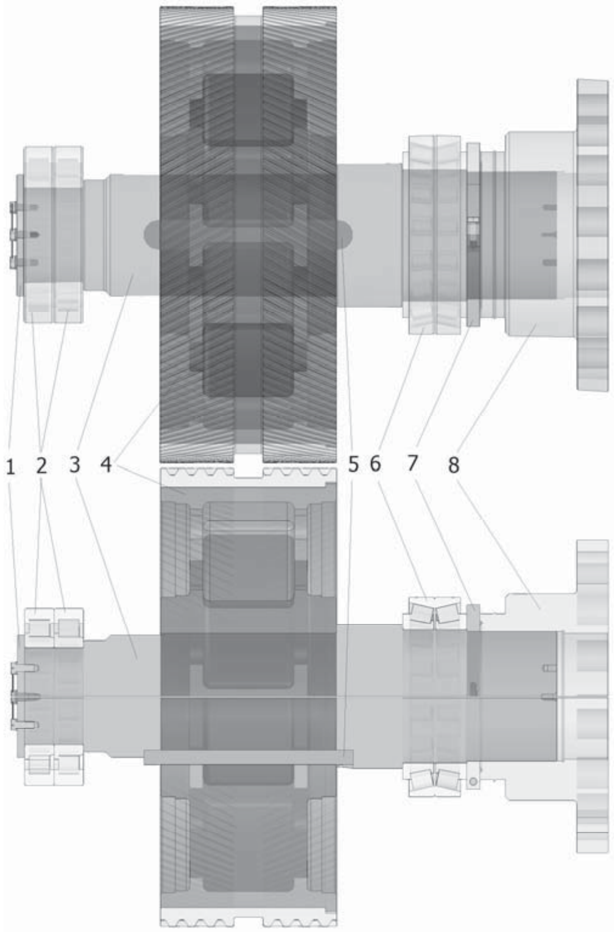


Fig. 6. *Construction of the outlet shaft*

Construction of the outlet shaft is shown in Fig. 6 and is made up of:: 1 – bearing fixing cover; 2 –hradial bearing with NU 252 cylindrical rolls; 3– shaft; 4 – gear wheel z = 134, m = 8 with left and right teeth; 5 – up to 80x40; 6 – radial-axial bearing with conic rolls on two rows 35072; 7 – semi-rings to block bearings; 8 – rigid semi-coupling with bolts. Axial forces in gear wheel gears, mark 4, are annulled by the body of the wheel. The wheel can move axially on the shaft to make an as good as possible reduction, with the two intermediary gear shafts. Axial forces transmitted by the driving wheel shaft are taken over and transmitted to the case of the reduction gear by the radial –axial bearing with conic rolls in two rows. The gear wheel is a compound construction, having the crown of alloyed steel and the shaft of carbon steel. Te two parts are assembled by a tightening adjustment.

4. Transmission verification of the winding machine reduction gear

Calculation breviary of the reduction gear gears has been developed in the study, from the technical characteristics of the reduction gear, based on the number of teeth, of the normal module and inclination angle of the teeth. The distance between the axis of the gear wheels axes and the outside diameter of the wheels, coinciding with those shown in the technical documentation of the reduction gear has been verified in the study, calculating the geometrical elements of the teeth.

The selection of the inclination level of the teeth at the level of seconds(βI = 29°32'30"; βII = 28°57'17") is explained only by its use as variable element to obtain whole values of distances between the reduction gear axes of 600, and 800 mm , respectively. The use of such values leads to difficult processing of the teeth, from the point of view of adjustment of the rectification machine and control of teeth, making the interchanging of gar wheels impossible Obtaining the contact spot corresponding to precision class 8 (40x50%) between the teeth sides in the reduction, especially the central wheel with the two shafts, is done by running in the reduction or the reduction gear after their being assembled on special stands.

Therefore, in the manufacturing method a resistance verification was made of the teeth to fatigue by contact pressure(SH) and bending fatigue at the base of the tooth(SF) depending on the width of the gear wheel (b), and the variation of the safety coefficients is shown on Fig. 7, thus: a – for the first reduction 61/113, m = 6 mm; b – for the second 41/134, m = 8 mm. In the loading cyclogram of the reductions it has been considered that 5% of the functioning of 10 000 hours, the reduction is overloaded up to 2 times (1000 kW), as in the case of load starts, and the reduction operates with medium shocks on a mining machine with a factor of use of 2.

The diagrams shown above and the calculation breviary in the study showed that:

- variation of safety coefficient in fatigue by contact pressure for the cemented steel pinion, SH_1 , and the alloyed steel improvement geared wheel, SH_2, vary function of the width of the teeth in a narrow range;
- variation of the safety coefficient in fatigue by bending at the base of the tooth for the cemented steel pinion, SF_1, and the alloyed steel improvement geared wheel, SF_2 , vary function of the width of the teeth in a large range;
- for teeth widths lower than 60%, 80 mm, and 120 mm, respectively, the safety coefficient decreases under the admitted value (SHa = 1,15; SFa = 1,25);
- in order to confirm the calculation breviary of the gears, the hardness of the teeth in the reduction gear wheels should be measured, which is difficult to be performed without the reduction gear having been demounted, and from the hardness measurements performed on the on the teeth of the changed wheels resulted that the pinion on shaft I has cementing steel hardness, the pinion and the geared wheel on shaft II have much lower hardness, under 300 HB;
- in the case of changing a geared wheel in the reduction gear a rapid running in of the gear is required with abrasive suspension by sealing the bearings, suspending the cables and using brakes to carry out the braking momentum until a contact spot is obtained corresponding along one and the other rotation sense.

Verification of the reduction gear shafts had been achieved by determining the reactions in the ball bearings, the bending momentums and the equivalent tensions in the critical sections of the shaft. Similarly, assembling by wedges of the geared wheel to the shaft, durability of the bearings and shaft deformation had been verified.

For an OLC 45 steel for shaft execution, for an admitted strain of150 N/mm^2, higher safety coefficient values than 9 result (CsaI = 17,2; CsaII = 15,07; CsaIII = 9,26).

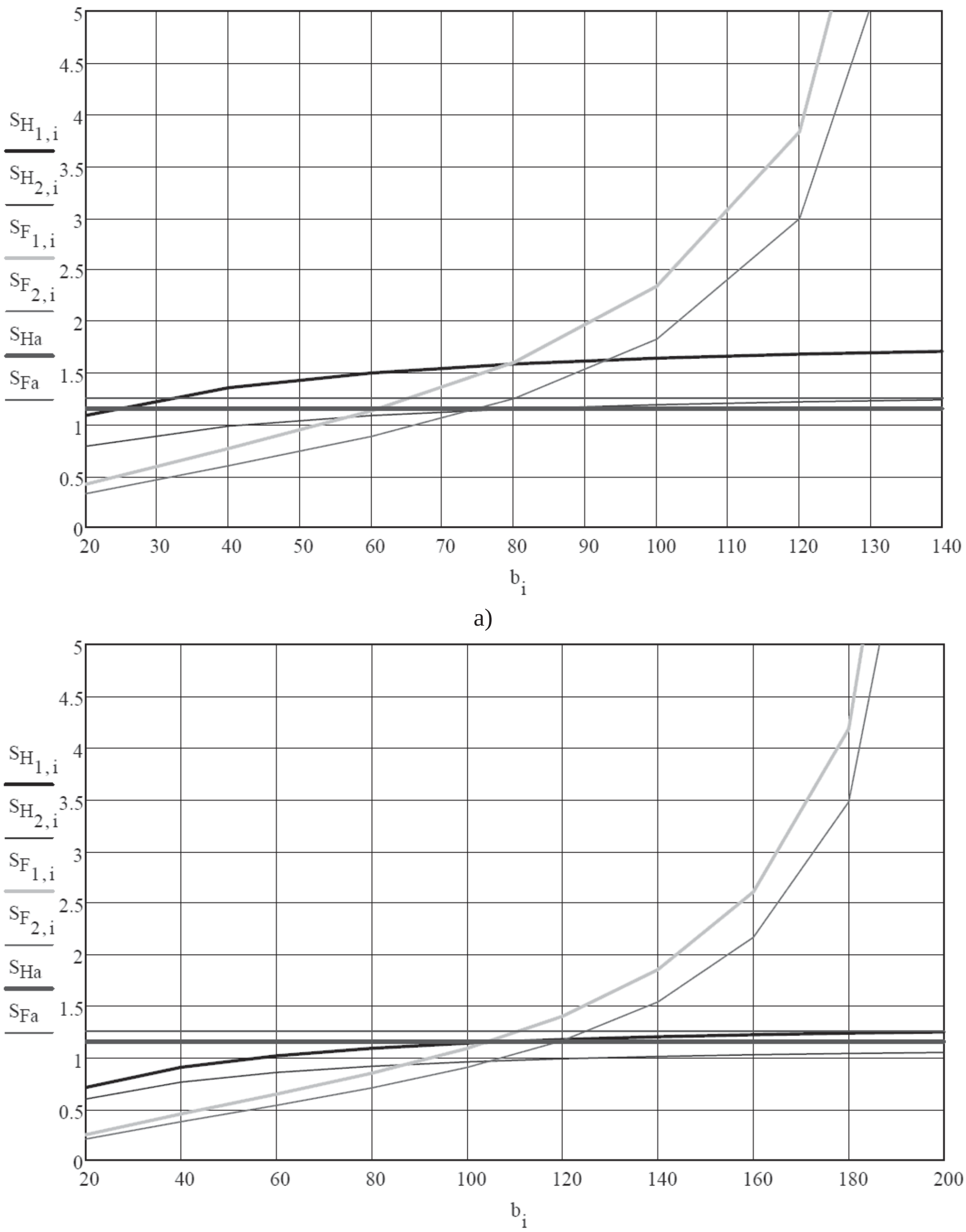
In the case of the central shaft, of outlet from the reduction gear, the case of reduction gear actuating had been considered with a single motor so that in the case of actuating with both motors the shaft would not be strained due to balancing the forces by the central wheel.

Assembling by wedges of the geared wheels on the shaft had been verified at contact pressure, where higher values than 3 of the safety coefficient had been resulted, and sharing, where higher safety coefficients than 11,8 had been found.

Minimum bearing durability of the bearings on shaft II is 737 700 hours, much higher than the 360 000 hours obtained for 50 years, 300 days per year and 24 hours per day of functioning of the reduction gear.

Deformation deflections of the shafts in various points are lower than the minimum admitted values

(fI = 0,007; fII = 0,034; fIII = 0,014 mm).



a)

b)

Fig. 7. *Variation of safety coefficients of the two reductions of the reduction gear*

Tolerance of deviation of the tooth direction along the contact length of 160 mm(the first gear) and 230 mm(the second gear) for 8 class of precision is Fβ=0,040 mm , and for class 7 is Fβ=0,020 mm, STAS 6273-81, tab.11, resulting tgαI = 2,5 10^{-4} and tgαII = 1,7 10^{-4} for F_{β}=0,040 mm and tgαI = 1,25 10^{-4} and tgαII = 8,5 10^{-5} for F_{β}=0,020 mm.

The admitted deviation of the deformation angle of the shafts given in the literature is ≤ 10^{-4} or α ≤ 10^{-4} rad ([2] page 269).

The deformation angles of shafts Ii and III in the area of geared wheels, point 2, is in vertical plane φII = 7,33 10^{-5} and φIII = 1,96 10^{-5} close to the admitted value of 10 10^{-5} especially for shaft III, the first gear.

If there is no running in of the reduction gear and the deformations of the shaft with the processing deviations are cumulated, then the contact spot is reduced and moves towards the extremity of the wheel, leading to the wear of the contact area or even to breaking the teeth.

5. Conclusions

The verification of the reduction gear transmission showed that the value of the safety coefficient in fatigue by bending at the base of the tooth is lower than the admitted value of 1,25, in case of gearing for widths smaller than 60% of the width of the wheel.

The construction of the V shaped geared wheels at inclination angles (β_I = 29°32'30", β_{II} = 28°57'17") leads to difficult processing of the teeth, from the point of view of adjusting rectification machine and teeth control.

If for the first step of the reduction gear an axial adjustment of the wheel positioning on the shaft for and adjustment of the contact spot, for the second step, on the central wheel, the construction is fixed, having no possibility of adjustment for the contact spot.

From the above it results that these reduction gears are unique, their total change being necessary in case a defect occurs in the transmission by geared wheels, since it is almost impossible to interchange the geared wheels in conditions of exploitation of the winding machine.

References

1. Pavelescu, D.
Organe de maşini, vol. 1
Editura Didactică şi Pedagogică, Bucureşti, 1985.

2. Cozma B., Urdea Gh., Dumitrescu I., Itu V.
Loads Transmitted to the Tower of the Hoisting Installation „Piscu Shaft" Mining Plant Aninoasa.
Al X-lea Simpozion Internațional „Tinerii şi cercetarea multidisciplinară", Buletin ştiințific al Universității „Politehnica" din Timişoara, domeniul Transactions on Mechanics, tom 53 (67), fasc. S4,2008.

3. Itu R.B., Dumitrescu I., Itu V.
Correlating 2K-52MU Cutting and Loading Machine With TR-5 Scraper Conveyer
7th Symposium, Durability and reability of Mechanical System, SYMECH 2014, Editura Academica Brâncuşi, ISSN 1844-640X, Pages 110-119

4. Urdea Gh., Cozma B., Dumitrescu I., Itu V.
Diagnosis of Braking Mechanism of Hoisting Device „Blind Shaft No. 9" of the Mining Plant Aninoasa.
Al X-lea Simpozion Internațional „Tinerii şi cercetarea multidisciplinară", Buletin ştiințific al Universității „Politehnica" din Timişoara, domeniul Transactions on Mechanics, tom 53 (67), fasc. S4,2008.

5. Ridzi M.C., Dumitrescu I., Itu V.
Studiul privind funcționarea maşinii de extracție Puț vechi cu schip de la E.M. Lonea
C.A. nr.182/8.10.2013, E.M. Lonea.