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# DEFINING OF MODEL FOR DETERMINING THE SERVICE LIFE OF HOISTING ROPES IN MINING***

***Abstract***

*The aim of this paper is to create an adequate model of relationship between the tensile strength and tearing force of the rope and its exploitation time. Analyzing the obtained laboratory data a mathematical model is chosen in order to achieve a good agreement with data. Using this model, it is possible to compute (approximately) the values of average tensile strength* $\overline{R}$ *and tearing forces sum F of the rope at arbitrary time moment t. Consequently, the values of these parameters can be predicted in the given time interval, as well as the exploitation time of rope.*

***Keywords****: average tensile strength, tearing forces sum, exploitation time of rope*

## 1 INTRODUCTION

The service life of steel hoisting ropes is defined by complex conditions of mechanical and corrosive wear prevailing in a mine shaft. Mechanical wear is the result of static and dynamic stress affecting the rope during its service life (tensile strain, bending, torsion and other). Corrosive wear is the result of specific working conditions prevailing in a mine shaft, such as: acid mining water with pH<4, aggressive mining gases (oxygen, carbon dioxide, hydrogen sulfide and other), airborne dust, high humidity, high temperature, absence of daylight, etc.

During service life of the rope, there are changes at the rope itself, demonstrated by occurrence of broken wires and reduction of cross-sectional area. The occurrence of broken wires occurs at the base due to the fatigue of wire material, and less often due to the effect of tensile forces onto reduced cross-section. The reduction of cross-section of the rope occurs as the result of mechanical wear and due to the effect of corrosion. Both factors, mechanical and corrosive wear, may occur independently or together, what depends on prevailing conditions in the shaft, rope quality, lubrication and maintenance quality, etc.

During service life, the rope is the most exposed to stresses at the joint with hoisting vessel due to the dynamic stresses born by the rope at the beginning of drive, as well as due to the abrupt change in velocity. Therefore, every 5 to 6 months (as

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provided by the Mining regulations), pieces of rope, with length of 1 to 2 m are cut in this part of the rope for the purpose of laboratory tests.

Some authors believe that the performed laboratory tests on a part of the rope at the joint with hoisting vessel cannot be taken as absolute criterion for determination of rope condition. Therefore, it is necessary to carry out the additional "in situ" test along the whole rope using the magnetic-inductive method in order to establish the condition of the whole rope and register changes, occurred due to deterioration and wear of the rope.

Taking all those above mentioned facts into account, the authors of this paper have proposed a mathematical model, which enables to predict a moment of reaching limiting values of the average tensile strength $\overline{R}$ and aggregate breaking force of the rope F, and thereby to predict a service life of the rope.

## 2 RESULTS OF LABORATORY TESTS ON STEEL HOISTING ROPE

Steel hoisting ropes for the purposes of mining are produced of high quality steel, with nominal tensile strength of wire material 1570 MPa or 1770 MPa, depending on construction and rope type. At the same time, those are also minimum tensile strengths, up to which the strength of wires is allowed to be reduced during service life of the rope.

When carrying out the laboratory tests of the rope, breaking force $F_m[N]$ and tensile strength of wire material $R_m[MPa]$ have to be established. Thereby, the aggregate breaking force of the rope, as well as the average tensile strength of wire material has to be calculated. Based on the results obtained, the evaluation on further usability of the rope, pursuant to the SRPS C.H1.030 Standard and the Rulebook on Technical Standards for Transportation of People and Material through the Mine Shaft, has to be given.

In order to evaluate the quality of wire material as well as the whole rope, the results of laboratory tests for the steel hoisting rope, which was used for about 10 years, and is still in use, were taken into consideration. During this period of time, 9 laboratory tests (approximately one test annually) were carried out. The results of tests are given in Table 1. [1]

**Table 1** *Results of laboratory tests on hoisting rope*

| Test serial number | Aggregate breaking force of the rope ΣF [N] | Average tensile strength of wire material $\overline{R}\,[MPa]$ |
|---|---|---|
| 1. (a new rope) | 358786 | 1886.88 |
| 2. (I test) | 352650 | 1864.38 |
| 3. (II test) | 351139 | 1860.25 |
| 4. (III test) | 357751 | 1886.05 |
| 5. (IV test) | 357339 | 1879.95 |
| 6. (V test) | 354144 | 1873.76 |
| 7. (VI test) | 352847 | 1866.23 |
| 8. (VII test) | 354180 | 1871.19 |
| 9.(VIII test) | 352866 | 1861.40 |

Steel hoisting rope that was examined, with structure wj+6(9+9+1) Seale, has the computationally obtained breaking force $F_{computational}$=332390 N and nominal tensile strength of wire material $R_m$=1770 MPa.

Pursuant to the SPRS C.H1.030 Standard and the Rulebook on Technical Standards for Transportation of People and Material through the Mine Shaft, the rope has satisfactory quality if the aggregate breaking force of the rope, measured in a laboratory is higher than the computational breaking force of the rope ($F_{measured}>F_{computational}$) and if the average tensile strength of wire material is higher than the nominal tensile strength of wires ($\overline{R}>R_m$).

Analyzing the laboratory test results after ten years of rope utilization in a mine shaft, it was established that the measured values of the aggregate breaking force of the rope and average strength of wires are still slightly higher than minimum prescribed values of $F_{computational}$ and $R_m$, so the rope may be used in the mine for a brief period of time. Due to small differences between measured and allowed values, the service life of the rope is at the very end, and therefore the rope must be replaced by the new one.

## 3 MATHEMATICAL MODEL FOR DETERMINING THE SERVICE LIFE OF HOISTING ROPE

By testing the rope at specific time intervals, the breaking force and tensile strength are followed. Based on the obtained measurement results, it is possible to find the type of dependency between breaking force and tensile strength and time. As breaking force equals the product of tensile strength and cross-sectional area, wherefrom follows that the dependencies of the average breaking force $F$ on average tensile strength $\overline{R}$ is of the following type:

$$F = k \cdot \overline{R}$$

The value of $k$ parameter is found in a condition that the linear function $F = k \cdot \overline{R}$ approximate the most optimally the data from Table 1 in the sense of method of the smallest squares, and it amounts *k=189.42.* Hence, it is

$$F = 189.42\overline{R} \qquad (1)$$

whereby the index of curvilinear dependency is $\rho_F = 0.940383487$, which means that the dependency is "very strong".

Analyzing the obtained data, it can be concluded that the best compliance with laboratory data for $\overline{R}$ depending on time was given by a cubic regression model. [2], [4]

In order to apply the method of the smallest squares for obtaining regression model, we shall take the data from the Table 1 in such a way, that we shall consider the first year of testing as zero and take into account only the year in which the rope was tested, and instead of average tensile strength $\overline{R}$ we shall observe the variable $Z = \overline{R} - \overline{\overline{R}}$, where $\overline{\overline{R}}$ =1872.233MPa is arithmetic mean of the obtained average strengths. In this way we obtain dependency $Z$ on $t$ as shown in Table 2.

**Table 2** *Dependency of the variable Z on the time t*

| ***t*** | 1 | 2.667 | 3.5 | 4.583 | 5.5 | 6.75 | 7.833 | 8.333 | 8.833 |
|---|---|---|---|---|---|---|---|---|---|
| ***Z*** | 14.647 | -7.85 | -11.986 | 13.820 | 7.715 | 1.527 | -6.003 | -1.040 | -10.830 |

Based on the data from Table 2, the following cubic regression model is obtained:

$$Z=46.75 - 40.69t + 8.95t^2 - 0.58t^3 \quad (2)$$

whose graph is shown in Figure 1.

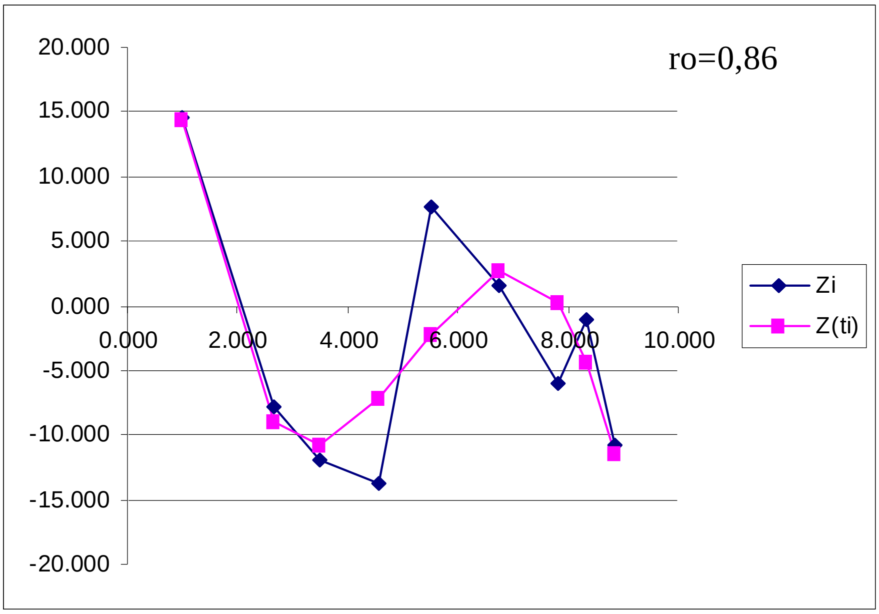


**Figure 1** *Curve of tensile strength dependency on time*

Index of curvilinear dependency is $\rho_z$=0.86, which indicates that there is a "strong" dependency among data from Table 2, which is expressed by equation (2). [3]

By applying equation (2), it is possible to find the values of variable *Z*, i.e. values of the average tensile strength $\overline{R}$ within the arbitrary time moment *t*, and then by using equation (1) to find the values of aggregate breaking force *F* as well.

### 3.1 Verification the model on tested rope

The checkup of proposed mathematical model was made on the steel hoisting rope, which was in use for about 10 years, with structure wj+6(9+9+1) Seale, with computationally found breaking force $F_{computational}$= =332390 N and nominal tensile strength of wire material of $R_m$=1770 MPa.

By applying the proposed mathematical model, the following indicators result:

If the time period of rope usage is t=9.5 years, it follows that it is Z=-29.345, i.e. the average tensile strength of wires is $\overline{R}$ = =1872.233-29.345=1842.887 MPa, and the aggregate breaking force of the rope is $F_{aggregate}$=349079.66 N.

For the time period of the rope usage of t=10 years, it is obtained that it is Z=-45.15, i.e. the average tensile strength of wires is $\overline{R}$ =1872.233-45.15=1827.082 MPa, and the aggregate breaking force of the rope is $F_{aggregate}$=346085.87 N.

The obtained values are close to the measured values in laboratory and they are higher than minimum prescribed values $F_{computational}$ and $R_m$, which indicate that the rope may be used further in the mine. By this, the accuracy of the model and its conformity with the laboratory results and actual condition on site are confirmed.

Accordingly, by the use of the proposed model, the time moment *t* can be determined when limiting values, allowed by the Standard and Mining Regulations, have to be reached, which are: $F_{computational}$=332390 N and $R_m$=1770 MPa.

Namely, for $F_{computational}$=332390 N from equation (1), $\overline{R}$ =1754,78 MPa is obtained, and then Z=-117.455; then from the equation (2),the time of the rope usage is obtained that amounts t=11.47 years.

For $R_m$=1770 MPa, firstly Z=-102.233, is obtained and then from the equation (2), the time of the rope usage is obtained that amounts amounting t=11.21 years.

Predicted service life of the rope, obtained by this model, amounts approximately 11 years, which corresponds to the actual service life of the rope in the mine.

Based on the aforementioned statements, it can be concluded that the service life of rope in the mine can be predicted with considerably large reliability using the proposed model, and thereby the expensive laboratory and field "in situ" tests on ropes can be avoided.

## 4 CONCLUSION

The evaluation of the rope quality, based on the results, obtained from laboratory tests on a part of rope at its joint with hoisting vessel was proved to be insufficient, which is the reason why the periodical additional field tests and controls of installed steel ropes have to be carried out, in order to establish the resistivity condition of the whole rope and changes, caused by deterioration and wear of the rope. All of this complicate and raise the costs of test procedure and evaluation or quality of the steel hoisting ropes.

The authors of this paper have proposed a mathematical model, based on which it is possible to predict the service life of used rope with considerably large reliability and to determine the moment of its replacement.

Analyzing the obtained data, it is concluded that the best compliance with laboratory data for the average tensile strength $\overline{R}$ depending on the time *t*, is given by the cubic regression model, as shown by the following equation:

$$Z=46.75 - 40.69t + 8.95t^2 - 0.58t^3 \quad (2)$$

Applying the proposed model, it is possible to find the value of average tensile strength $\overline{R}$ within the arbitrary time period *t*, and then indirectly the value of aggregate breaking force *F* as well and then, based on them, to establish the service life of rope.

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# DEFINISANJE MODELA ZA ODREĐIVANJE RADNOG VEKA IZVOZNIH UŽADI U RUDARSTVU[***]

***Izvod***

*Cilj ovog rada je da se napravi odgovarajući matematički model zavisnosti zatezne čvrstoće i sile kidanja užeta od vremena njegove eksploatacije. Analizom dobijenih laboratorijskih podataka bira se matematički model koji ima dobru saglasnost sa merenim podacima.*

*Koristeći ovaj model moguće je odrediti vrednosti prosečne zatezne čvrstoće* $\overline{R}$ *i zbirne prekidne sile užeta F u proizvoljnom vremenskom monentu t, pa na osnovu njih prognozirati vek eksploatacije užeta.*

***Ključne reči:*** *prosečna zatezna čvrstoća žica, zbirna prekidna sila užeta, vek eksploatacije užeta*

## 1. UVOD

Radni vek čeličnih izvoznih užeta definisan je vrlo složenim uslovima mehaničkog i korozionog habanja koji vladaju u oknu rudnika. Mehaničko habanje je posledica statičkih i dinamičkih naprezanja koja deluju na uže u toku njegove eksploatacije (naprezanja na zatezanje, savijanje, torziju i dr.). Koroziono habanje je posledica specifičnih radnih uslova koji vladaju u oknu rudnika, kao što su: kisele rudničke vode sa pH<4, agresivni rudnički gasovi (kiseonik, ugljendioksid, sumporvodonik i dr.), lebdeća prašina, visoka vlažnost, povišena temperatura, odsustvo dnevne svetlosti i dr.

U toku eksploatacije užeta dolazi do promena na samom užetu, koje se manifestuju pojavom prekinutih žica i smanjenjem površine poprečnog preseka. Pojava prekinutih žica javlja se u osnovi zbog zamora materijala žica, ređe zbog dejstva zateznih sila na oslabljeni presek. Smanjenje poprečnog preseka užeta javlja se kao posledica mehaničkog habanja i dejstva korozije. Oba faktora, mehaničko i koroziono habanje, mogu se pojaviti samostalno ili zajedno, što zavisi od uslova koji vladaju u oknu, kvaliteta užeta, kvaliteta podmazivanja i održavanja i dr.

Za vreme rada uže je najviše izloženo naprezanjima kod spoja sa izvoznim sudom, zbog dinamičkih naprezanja koje uže trpi pri započinjanju vožnje, kao i usled nagle promene brzine kretanja. Zbog toga se svakih 5 do 6 meseci (kako predviđaju rudarski propisi) na tom delu užeta odsecaju komadi užeta dužine od 1 do 2 m radi laboratorijskog ispitivanja.

Neki autori smatraju da izvršena laboratorijska ispitivanja na delu užeta kod spoja sa izvoznim sudom ne mogu biti uzeta kao apsolutni kriterijum za utvrđivanje stanja užeta. Zbog toga je potrebno povremeno izvršiti dodatna "in situ" ispitivanje duž celog užeta magnetno-induktivnom meto-

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[***] *Ovaj rad je proistekao kao rezultat projekta br. 33029 „Izučavanje mogućnosti valorizacije preostalih rezervi uglja u cilju obezbeđenja energetske stabilnosti Republike Srbije" finansiranog od strane Ministarstva prosvete, nauke i tehnološkog razvoja Republike Srbije.*

dom, kako bi se utvrdilo stanje kompletnog užeta i evindentirale nastale promene usled istrošenosti i habanja užeta.

Uzimajući u obzir napred pomenute činjenice, autori ovog rada su predložili matematički model kojim je moguće predvideti vremenski moment postizanja graničnih vrednosti prosečne zatezne čvrstoće $\overline{R}$ i zbirne prekidne sile užeta F, i shodno tome, prognozirati vek eksploatacije užeta.

## 2. REZULTATI LABORATORIJSKIH ISPITIVANJA ČELIČNOG IZVOZNOG UŽETA

Čelična izvozna užad za potrebe rudarstva proizvode se od izuzetno kvalitetnih čelika, nazivne zatezne čvrstoće materijala žica 1570 MPa ili 1770 MPa, zavisno od konstrukcije i vrste užeta. Istovremeno to su i minimalne zatezne čvrstoće do kojih sme opasti čvrstoća žica u toku eksploatacije užeta.

Prilikom laboratorijskog ispitivanja užeta utvrđuje se *sila kidanja $F_m$ [N]* i *zatezna čvrstoća materijala žica $R_m$ [MPa]*. Pri tome se računa zbirna prekidna sila užeta, kao i prosečna zatezna čvrstoća materijala žica. Na osnovu dobijenih rezultata daje se ocena o daljoj upotrebljivosti užeta na osnovu standarda SRPS C.H1.030 i Pravilniku o tehničkim normativima pri prevozu ljudi i materijala oknom rudnika.

Za ocenu kvaliteta materijala žica, kao i kompletnog užeta, uzeti su u razmatranje rezultati laboratorijskih ispitivanja čeličnog izvoznog užeta koje je bilo u upotrebi oko 10 godina i još se nalazi u eksploataciji. U tom periodu urađeno je 9 laboratorijskih ispitivanja (približno jednom godišnje). Rezultati ispitivanja dati su u tabeli 1. [1]

**Tabela 1.** *Rezultati laboratorijskih ispitivanja izvoznog užeta*

| Redni broj ispitivanja | Zbirna prekidna sila užeta ΣF [N] | Prosečna zatezna čvrstoća materijala žica $\overline{R}\,[MPa]$ |
|---|---|---|
| 1. (novo uže) | 358786 | 1886,88 |
| 2. (I ispitivanje) | 352650 | 1864,38 |
| 3. (II ispitivanje) | 351139 | 1860,25 |
| 4. (III ispitivanje) | 357751 | 1886,05 |
| 5. (IV ispitivanje) | 357339 | 1879,95 |
| 6. (V ispitivanje) | 354144 | 1873,76 |
| 7. (VI ispitivanje) | 352847 | 1866,23 |
| 8. (VII ispitivanje) | 354180 | 1871,19 |
| 9. (VIII ispitivanje) | 352866 | 1861,40 |

Ispitivano čelično izvozno uže, konstrukcije wj+6(9+9+1) Seale, ima računsku prekidnu silu $F_{računsko}$=332.390 N i nazivnu zateznu čvrstoću materijala žica $R_m$=1.770 MPa.

Prema standardu SRPS C.H1.030 i Pravilniku o tehničkim normativima pri prevozu ljudi i materijala oknom rudnika uže je zadovoljavajućeg kvaliteta ako je izmerena laboratorijski zbirna prekidna sila užeta veća od računske prekidne sile užeta ($F_{mereno}$>$F_{računsko}$) i ako je prosečna zatezna čvrstoća materijala žica veća od nazivne zatezne čvrstoće žica ($\overline{R} > R_m$).

Analizirajući laboratorijske rezultate ispitivanja posle deset godina korišćenja užeta u oknu rudnika konstatovali smo da su izmerene vrednosti zbirne prekidne sile užeta i prosečne zatezne čvrstoće žica i dalje nešto veće od minimalno propisanih vrednosti $F_{računsko}$ i $R_m$, pa se uže može još neko vreme koristiti na rudniku. S obzirom na male razlike između izmerenih i dozvoljenih vrednosti radni vek užeta je sasvim pri kraju, zbog čega se uže uskoro mora zameniti novim.

## 3. MATEMATIČKI MODEL ZA ODREĐIVANJE RADNOG VEKA IZVOZNOG UŽETA

Ispitivanjem užeta u određenim vremenskim intervalima, mi pratimo promenu sile kidanja i zatezne čvrstoće od vremena. Na osnovu dobijenih rezultata merenja, moguće je naći oblik zavisnosti sile kidanja užeta i zatezne čvrstoće od vremena. Kako je sila kidanja jednaka proizvodu zatezne čvrstoće i površine poprečnog preseka žice, sledi da je zavisnost prosečne sile kodanja $F$ od prosečne zatezne čvrstoće $\overline{R}$ oblika:

$$F = k \cdot \overline{R}$$

Vrednost parametra $k$ nalazimo iz uslova da linearna funkcija $F = k \cdot \overline{R}$ najbolje aproksimira podatke iz tabele 1. u smislumetode najmanjih kvadrata i ona iznosi *k=189,42*. Pa je,

$$F = 189{,}42\overline{R} \qquad (1)$$

pri čemu je indeks krivolinijske zavisnosti $\rho_F = 0{,}940383487$, što znači da je zavisnost "vrlo jaka".

Analizom dobijenih podataka zaključujemo da najbolju saglasnost sa laboratorijskim podacima za $\overline{R}$ u zavisnosti od vremena daje kubni regresioni model. [2], [4]

Da bismo primenili metodu najmanjih kvadrata za dobijanje regresionog modela, podatke u tabeli 1., ćemo uzeti tako što ćemo prvu godinu ispitivanja uzeti kao nultu i uzeti u obzir samo godinu u kojem je uže ispitivano, a umesto prosečne zatezne čvrstoće $\overline{R}$ posmatraćemo promenljivu $Z = \overline{R} - \overline{\overline{R}}$, gde je $\overline{\overline{R}}$ =1872,233 MPa aritmetička sredina dobijenih prosečnih čvrstoća. Na ovaj način dobijamo zavisnost $Z$ od $t$ datu u tabeli 2.

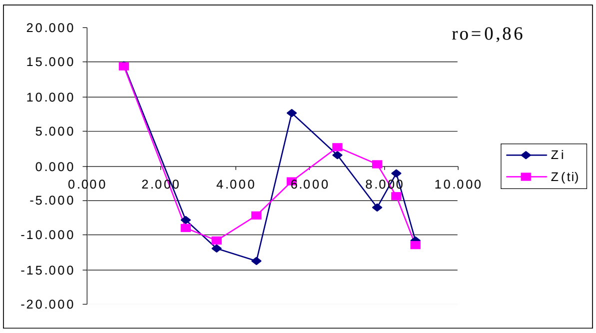
**Tabela 2.** *Zavisnost promenljive Z od vremena t*

| *t* | 1 | 2,667 | 3,5 | 4,583 | 5,5 | 6,75 | 7,833 | 8,333 | 8,833 |
|---|---|---|---|---|---|---|---|---|---|
| *Z* | 14,647 | -7,85 | -11,986 | 13,820 | 7,715 | 1,527 | -6,003 | -1,040 | -10,830 |

Na osnovu podataka iz tabele 2. dobijamo sledeći kubni regresioni model:

$$Z = 46{,}75 - 40{,}69t + 8{,}95t^2 - 0{,}58t^3 \quad (2)$$

čiji grafik je dat na sl. 1.




**Sl. 1.** *Kriva zavisnosti zatezne čvrstoće od vremena*

Indeks krivolinijske zavisnosti je $\rho_z = 0{,}86$, što ukazuje da između podataka u tabeli 2. postoji "jaka" zavisnost izražena jednačinom (2). [3]

Primenom jednačine (2) moguće je naći vrednosti promenljive $\underline{Z}$, tj. vrednosti prosečne zatezne čvrstoće $R$ u proizvoljnom vremenskom monentu $t$, a zatim korišćenjem jednačine (1) i vrednosti zbirne prekidne sile $F$.

### 3.1. Provera modela na ispitivanom užetu

Provera predloženog matematičkog modela urađena je na čeličnom izvoznom užetu koje je bilo u eksploataciji oko 10 godina, konstrukcije wj+6 (9+9+1) Seale, sa računskom prekidnom silom $F_{računsko}$ = 332.390 N i nazivnom zateznom čvrstoćom materijala žica $R_m$ = 1770 MPa.

Primenom predloženog matematičkog modela dolazimo do sledećih pokazatelja:

Ako je vremenki period korišćenja užeta t=9,5 godina, tada je Z =-29,345, tj. prosečna zatezna čvrstoća žica $\bar{R}$ =1.872,233-29,345 = 1.842,887 MPa, a zbirna prekidna sila užeta $F_{zbirno}$ = 349079,66 N.

Za vremenski period korišćenja užeta od t=10 godina, dobijamo da je Z = -45,15, tj. prosečna zatezna čvrstoća žica je $\bar{R}$ = 1.872,233 - 45,15 = 1827,082 MPa, a zbirna prekidna sila užeta $F_{zbirno}$ = 346085,87 N.

Dobijene vrednosti bliske su laboratorijski izmerenim vrednostima i veće su od minimalno propisanih vrednosti $F_{računsko}$ i $R_m$, što ukazuje da se uže može i dalje koristiti na rudniku. Ovim potvrđujemo tačnost modela i njegovo poklapanje sa laboratorijskim rezultatima i stvarnim stanjem na terenu.

Isto tako, predloženim modelom možemo odrediti vremenski moment *t* u kome se postižu granične vrednosti koje dozvoljava standard i rudarski propisi, a koje iznose: $F_{računsko}$ = 332.390 N i $R_m$ = 1.770 MPa.

Naime, za $F_{računsko}$ = 332.390 N iz jednačine (1) dobijamo $\bar{R}$ = 1.754,78 MPa, a zatim Z=-117,455, pa iz jednačine (2) dobijamo vreme korišćenja užeta od t=11,47 godina.

Za $R_m$ = 1770 MPa dobijamo prvo Z = -102,233, a zatim iz jednačine (2) dobijamo vreme korišćenja užeta od t=11,21 godina.

Prognozirani vek eksploatacije užeta dobijen ovim modelom iznosi oko 11 godina, što se poklapa sa stvarnim periodom eksploatacije užeta na rudniku.

Na osnovu svih prethodnih konstatacija možemo zaključiti da se predloženim modelom sa dosta velikom pouzdanošću može odrediti vek eksploatacije užeta na rudniku i time izbeći skupa laboratorijska i terenska "in situ" ispitivanja užadi.

## 4. ZAKLJUČAK

Ocena kvaliteta užeta na osnovu rezultata laboratorijskih ispitivanja na delu užeta kod spoja sa izvoznim sudom pokazala se nedovoljnom, zbog čega se povremeno moraju vršiti dodatna terenska ispitivanja i kontrole ugrađenih čeličnih užeta kako bi se utvrdilo stanje otpornosti kompletnog užeta i nastale promene usled istrošenosti i habanja užeta. Sve ovo jako usložnjava i poskupljuje proceduru ispitivanja i ocenu kvaliteta čeličnih izvoznih užadi.

Autori ovog rada predložili su matematički model na osnovu kojeg je moguće sa dosta velikom pouzdanošću prognozirati vek trajanja užeta u eksploataciji i odrediti trenutak njegove zamene.

Analizom dobijenih podataka zaključujemo da najbolju saglasnost sa laboratorijskim podacima za prosečnu zateznu čvrstoću $\bar{R}$ u zavisnosti od vremena *t* daje kubni regresioni model, dat sledećom jednačinom:

$$Z=46,75 - 40,69t + 8,95t^2 - 0,58t^3 \quad (2)$$

Primenom predloženog modela moguće je naći vrednost prosečne zatezne čvrstoće $\bar{R}$ u proizvoljnom vremenskom momentu *t*, a zatim posredno i vrednost zbirne prekidne sile *F*, pa na osnovu njih odrediti vek eksploatacije užeta.

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