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ANALIZA STANJA NAPONA-DEFORMACIJA KONSTRUKCIJE OBRTNE PLATFORME ROTORNOG BAGERA – OSNOVA EFIKASNE REKONSTRUKCIJE

ANALYSIS OF STRESS-STRAIN STATE OF BUCKET WHEEL EXCAVATOR REVOLVING PLATFORM STRUCTURE – FUNDAMENT OF EFFICIENT RECONSTRUCTION

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Ključne reči
- Rotorni bager
- Obrtna platforma
- Proračun čvrstoće
- Rekonstrukcija

Izvod

Rotorni bageri čine okosnicu sistema mehanizacije površinskih kopova. Njihova eksploatacija u ekstremno teškim uslovima prouzrokuje otkaze delova noseće konstrukcije (plastične deformacije, prsline, pukotine, lomovi). Kao konkretni primeri, u radu su najpre prikazani izgledi tipičnih oštećenja konstrukcija obrtnih platformi bagera TAKRAF SRs 1200×24/4 (400 kW) + VR. Potom su izloženi postupci proračuna njihove konstrukcije čiju osnovu čine dve etape: formiranje konačnoelementnih mreža i analiza opterećenja. Sprovođenjem izložene procedure proračuna, oblikovano je konstrukciono rešenje primenjeno prilikom rekonstrukcije obrtnih platformi dva bagera pomenutog tipa tokom 2005. godine. O valjanosti pristupa problemu i uspešnosti rešenja rekonstrukcije uverljivo govori podatak da su, nakon sanacije i rekonstrukcije, bageri otkopali više od 5 000 000 m^3 otkrivke, a da pri tome, u zonama rekonstrukcije, nisu konstatovani bilo kakvi defekti konstrukcija obrtnih platformi.

UVODNA RAZMATRANJA

Obrtna platforma predstavlja bazni deo nadgradnje rotornog bagera, na koji se oslanja toranj sa strelom protivtega. Ona prima celokupno opterećenje nadgradnje i prenosi ga, posredstvom radiaksijalnog ležaja, na donji stroj sa guseničnim mehanizmom za kretanje.

Tokom višegodišnje eksploatacije bagera TAKRAF SRs 1200×24/4 (400 kW) + VR u JP RB „Kolubara“, sl. 1, dolazilo je do pojava prslina i pukotina u strukturi obrtne platforme, u zoni oslanjanja zadnjih stubova tornja nadgradnje. Pomenuta oštećenja strukture platforme locirana su na donjoj ploči i vertikalnim limovima, sl. 2, 3, 4 i 5.

Keywords
- Bucket wheel excavator
- Revolving platform
- Strength calculation
- Reconstruction

Abstract

Bucket wheel excavators (BWE) are a part and parcel of the mechanization system in open pits. Their exploitation in heavy duty conditions causes failures of supporting structural parts (plastic deformations, cracks, fractures, breakages). As a real example, the paper first presents appearance of typical damages of revolving platform structures for BWE TAKRAF SRs 1200×24/4 (400 kW) + VR. Subsequently, techniques for calculating their structure are presented, whose basis is made in two stages: set up of finite element mesh and analysis of loads. The structural solution is developed by conducting the presented calculation procedure, and is applied during reconstruction of revolving platforms (2005) on two BWEs mentioned before. Validity of problem approach and efficiency of reconstruction solution is found in the fact that after reconstruction and repair BWE have excavated more than 5 000 000 m^3 of barren soil, while at reconstruction zones no defects of revolving platform structures have been detected.

INTRODUCTORY REMARKS

The revolving platform is a basic part of BWE superstructure, whereupon the tower with counterweight beam is built. It takes the total superstructure load and transmits it by radial-axial bearing to the lower structure with caterpillar mechanism for motion.

During several years operation of BWE TAKRAF SRs 1200×24/4 (400 kW) + VR in the Public Agency Mining Open Pit “Kolubara,” Fig. 1, cracks and fractures occurred in the revolving platform structure, in the rear columns support zone of superstructure tower. Structural damages of the platform are located on the lower plate and vertical panels, Figs. 2, 3, 4 and 5.

Slika 1. Bager TAKRAF SRs 1200 × 24/4 (400 kW)
Figure 1. BWE TAKRAF SRs 1200 × 24/4 (400 kW).

Slika 2. Pukotine na donjoj ploči obrtne platforme (spolja)
Figure 2. Cracks on lower plate of revolving platform (outside).

Slika 3. Pukotine na vertikalnom limu obrtne platforme (spolja)
Figure 3. Cracks on vertical panel of revolving platform (outside).

Slika 4. Pukotine na donjoj ploči i vertikalnom limu obrtne platforme (iznutra)
Figure 4. Cracks on lower plate and vertical panel of revolving platform (inside).

Na osnovu komparativne analize rezultata proračuna naponsko-deformacionog stanja originalne konstrukcije obrtne platforme i nekoliko varijanti njenog konstrukcionog poboljšanja, autori ovog rada razvili su:

- Konstrukciono rešenje strukture obrtne platforme koje zadovoljava kriterijume čvrstoće i elastične stabilnosti, kao i zahtev da se rekonstrukcija izvede bez demontaže nadgradnje;
- Tehnologiju zamene i sanacije teško oštećenih delova strukture obrtne platforme.

On the basis of comparative analysis of calculated results of stress-strain state of original revolving platform structure and several variants of its structural improvement, authors of this paper have developed:

- Structural solution of revolving platform construction that satisfies criteria of strength and elastic stability, also as requirement that the reconstruction has to be done without superstructure disassembling;
- Technology for replacement and repair of damaged parts of revolving platform structure.

KONAČNOELEMENTNI MODEL ORIGINALNE KONSTRUKCIJE OBRTNE PLATFORME

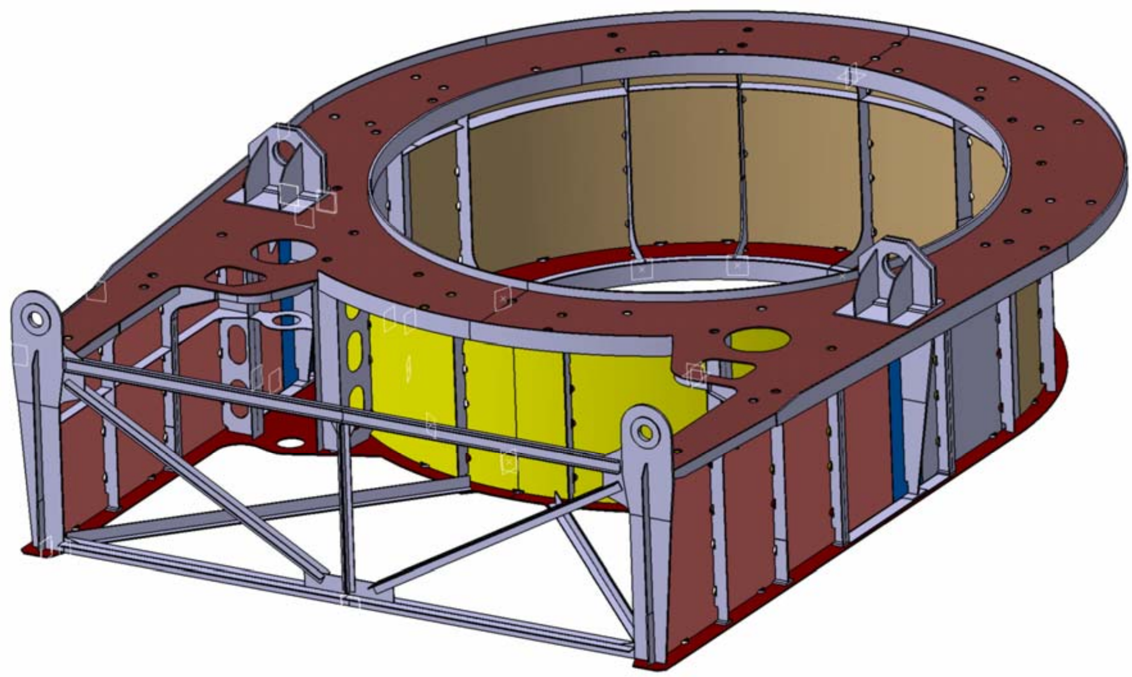
Konstrukcija obrtne platforme, čiji je 3D model, sl. 5, formirana na osnovu originalne konstrukcione dokumentacije, oblikovana je saglasno nameni (prenošenje opterećenja) i čine je dva osnovna poddomena:

- cilindrični nosač koji se oslanja na radiaksijalni ležaj;
- dva konzolna nosača elastično uklještena u cilindrični nosač, za koje se posredstvom odgovarajućih uški vezuje rešetkasta konstrukcija tornja sa strelom protivtega.

FINITE ELEMENT MODEL OF ORIGINAL STRUCTURE OF REVOLVING PLATFORM

Revolving platform structure with 3D model, presented in Fig. 5, is setup on the basis of original technical documentation, and shaped according to its purpose (load transmission) and consists of two basic subdomains:

- cylindrical girder supported on radial-axial bearing;
- two cantilever girders elastically fixed in cylindrical girder, and connected by corresponding eyes to the tower truss structure with counterweight beam.



Slika 5. 3D model konstrukcije obrtne platforme, /2/
Figure 5. 3D model of revolving platform structure, /2/.

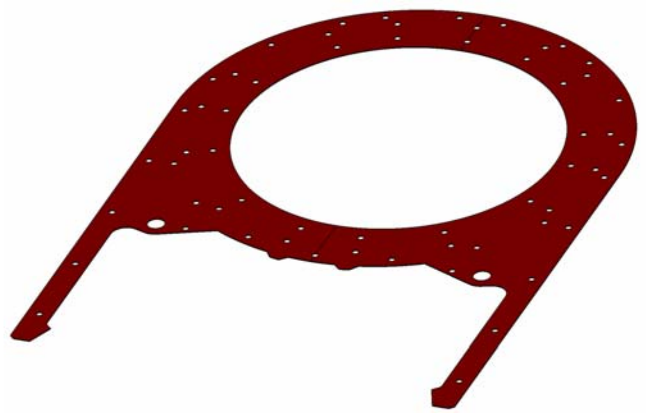
Osnovni konstrukcioni elementi obrtne platforme su:

- gornja ploča, sl. 6;
- donja ploča, sl. 7;
- vertikalni lim koji vezuje gornju i donju ploču, formirajući cilindrični nosač i konzolne nosače stubova nadgradnje, sl. 8;
- rebra, odnosno, ukrućenja vertikalnog lima, sa ojačanjima donje ploče, sl. 9.

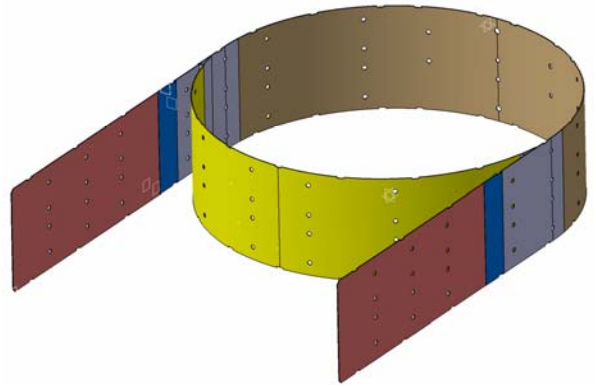
Basic structural parts of the revolving platform are:

- upper plate, Fig. 6;
- lower plate, Fig. 7;
- vertical panel connecting upper and lower plate, making cylindrical girder and cantilever girders of superstructure columns, Fig. 8;
- Ribs, i.e. stiffening of vertical panel with strengthening of lower plate, Fig. 9.

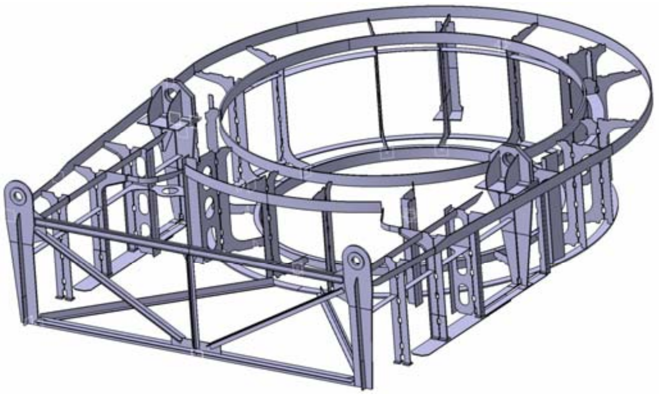
Slika 6. 3D model gornje ploče, /2/
Figure 6. 3D model of upper plate, /2/.



Slika 7. 3D model donje ploče, /2/
Figure 7. 3D model of lower plate, /2/.



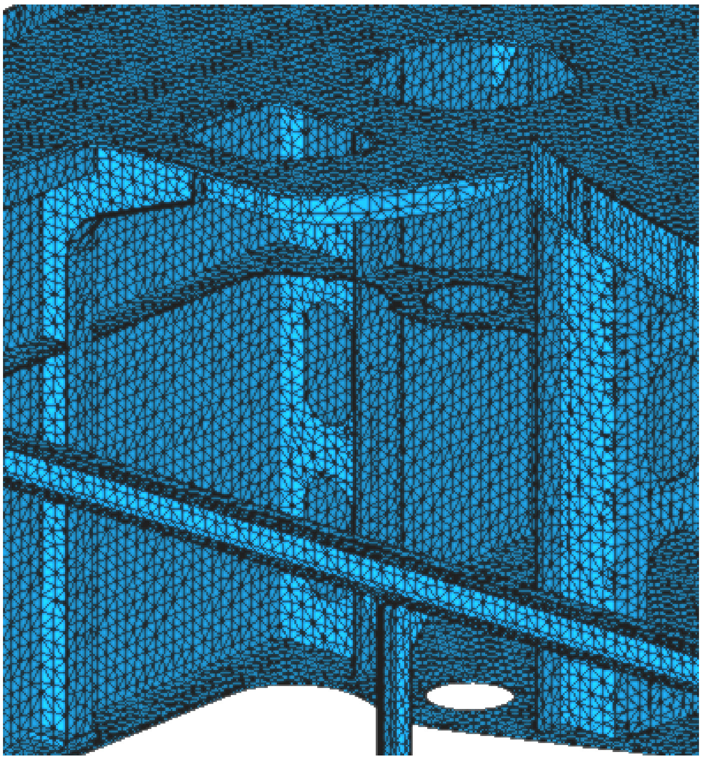
Slika 8. 3D model vertikalnog lima, /2/
Figure 8. 3D model of vertical panel, /2/.



Slika 9. 3D model ukrućenja konstrukcije platforme
Figure 9. 3D model of platform structure stiffening.

Trodimenzionalni model konstrukcije obrtne platforme, sl. 5, diskretizovan je konačnim elementima tipa tetraedra. Generisana konačnoelementna mreža sadrži 1 035 538 elemenata. Detalj mreže u zoni pojave prslina i pukotina prikazan je na sl. 10.

3D model of revolving platform structure, Fig. 5, is discretized by tetrahedron finite elements. The mesh consists of 1 035 538 finite elements. Generated detail of the mesh in the zone of cracks and fracture appearance is shown in Fig. 10.



Slika 10. Konačnoelementna mreža u kritičnoj zoni, /2/
Figure 10. Detail of FE mesh in the critical zone, /2/.

ANALIZA SPOLJAŠNJEG OPTEREĆENJA KONSTRUKCIJE OBRTNE PLATFORME

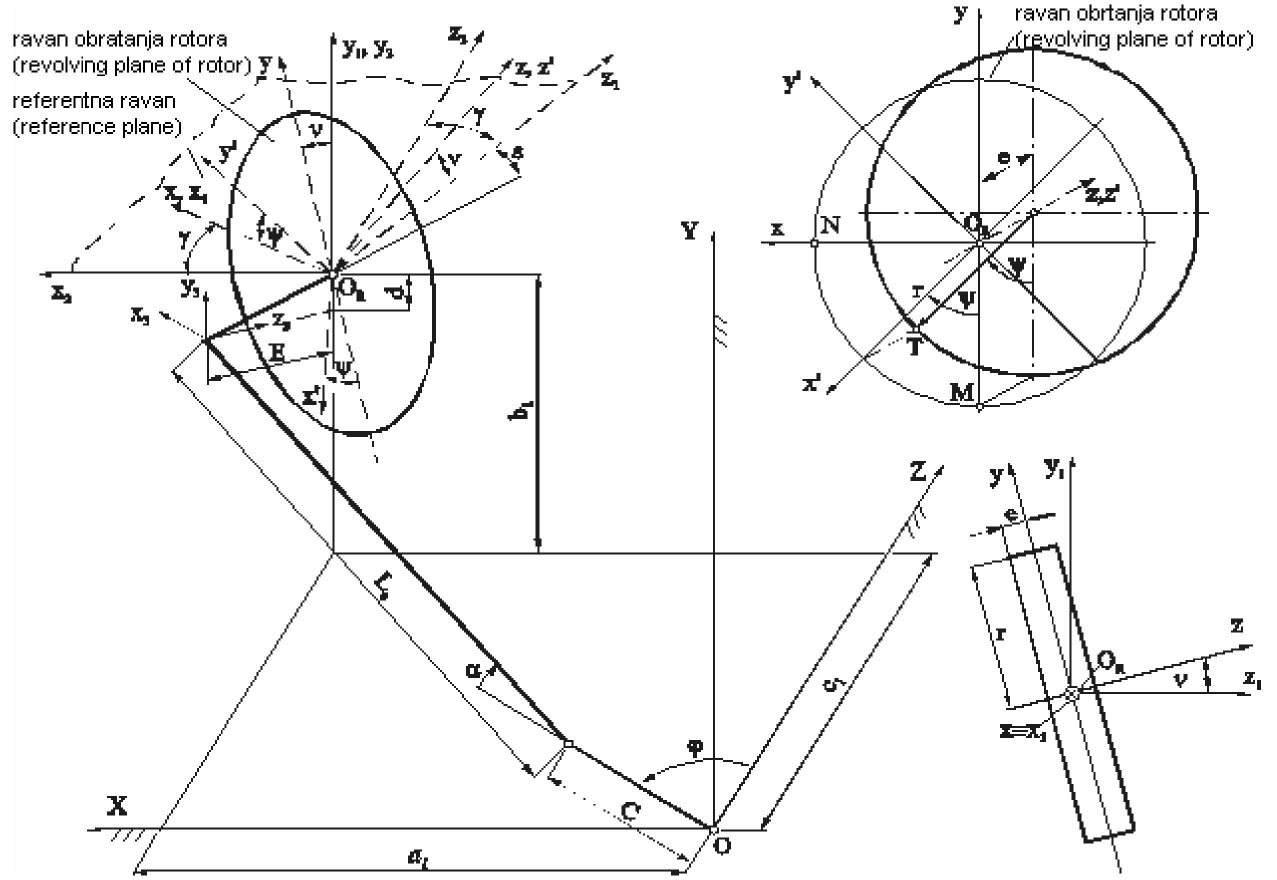
Analiza naponsko-deformacionog stanja konstrukcije obrtne platforme izvedena je saglasno odredbama standarda DIN 22261-2, za slučaj dejstva glavnih opterećenja - H. Ovaj slučaj obuhvata kombinacije opterećenja koja stalno deluju u toku rada bagera. To su: stalno opterećenje od sopstvenih težina (**E**), težina transportovanog materijala (**F**), težina kore - nalepljenog materijala tla (**V**), opterećenja od dejstva vetra (**W**), opterećenja usled nagiba (**N**), obimna sila na rotoru (**U**), bočna sila (**S**) i dinamička opterećenja (**D**).

ANALYSIS OF EXTERNAL LOADS OF REVOLVING PLATFORM STRUCTURE

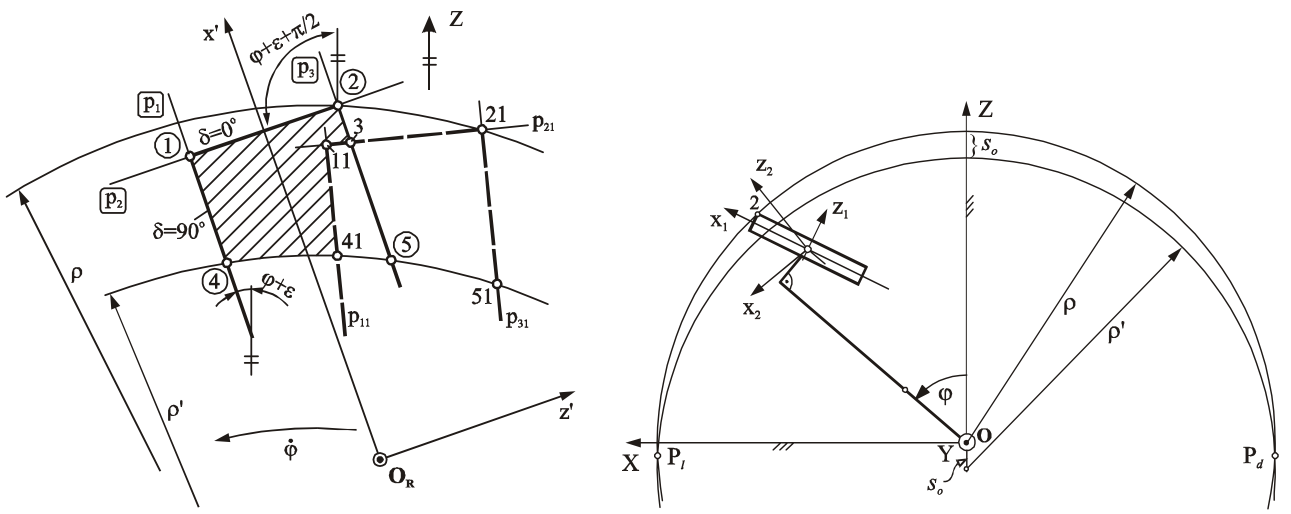
Analysis of stress-strain state of revolving platform structure is done according to standard DIN 22261-2, for the case of main loads - H. This case includes combination of loads permanently acting during BWE operation, and are: permanent load due to self weight (**E**), weight of conveyed material (**F**), weight of bark – adherent residual soil (**V**), loads due to wind action (**W**), loads due to slope (**N**), tangent force on bucket wheel (**U**), lateral force (**S**), and dynamic loads (**D**).

Interesantno je napomenuti da se prilikom identifikacije obimne i bočne sile na rotoru, prema standardu DIN 22261-2, zanemaruju uticaji njegovih ekscentriciteta u odnosu na sistemske linije strele i nagiba u odnosu na vertikalnu i horizontalnu ravan. Zato je u istraživanjima koja su prethodila ovom radu, /3/, na osnovu modela koji obuhvata navedene uticaje, sl. 11, razvijen originalni softver koji omogućava da se pri bilo kom položaju strele odrede uticaji otpora kopanja, sl. 12.

It is of interest to state that the determination of tangent and lateral forces on bucket wheel, according to DIN 22261-2, neglects effects of bucket wheel eccentricity in relation to system lines of beam and the inclination from vertical and horizontal planes. Therefore, the research that forerun this paper, /3/, as based on the model containing mentioned effects, Fig. 11, an original software was developed that enables defining influence of resistance to excavation in any position of beam, Fig. 12.



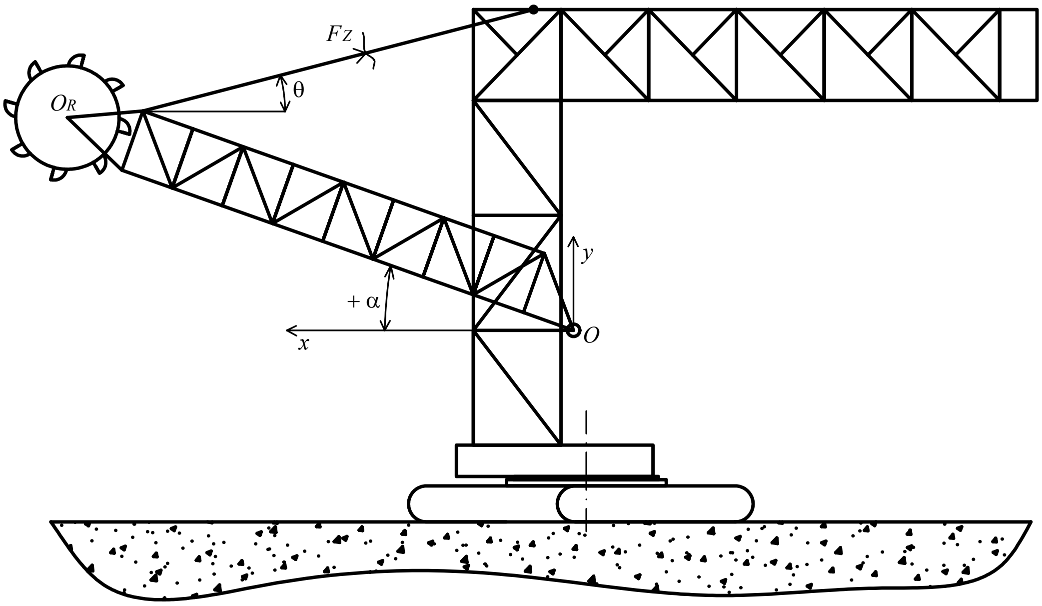
Slika 11. Kinematički model rotornog bagera, /3/
Figure 11. Kinematical model of BWE, /3/.



Slika 12. Proračunske sheme za određivanje geometrijskih parametara odreska, /3/
Figure 12. Calculation schemes for defining chip geometry parameters, /3/.

Nadgradnja bagera predstavlja strukturu izmenljive geometrije, zato što ugao nagiba strele rotora u odnosu na horizontalu (α) može da se menja u dijapazonu α_{max} = 14,5° do α_{min} = –23,42°, sl. 13.

The BWE superstructure is a structure of changeable geometry, because the inclination angle of bucket wheel related to horizontal line (α) can change in the scope α_{max} = 14.5° to α_{min} = –23.42°, Fig. 13.



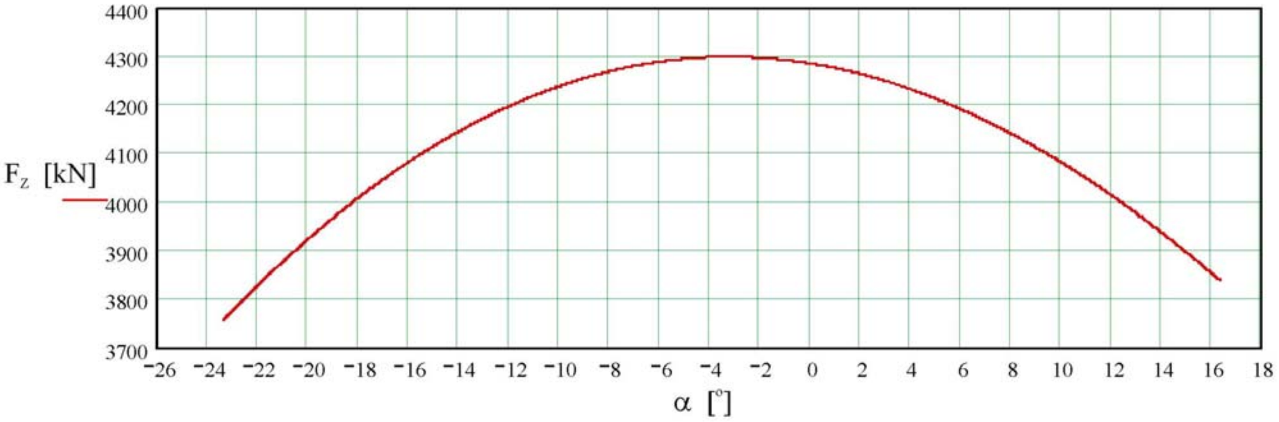
Slika 13. Proračunski model za određivanje uticaja strele rotora na toranj i strelu protivtega, /2/
Figure 13. Calculation model for determining influence of bucket wheel beam on the tower and counterweight beam, /2/.

Promena položaja strele rotora dovodi do promene:
- položaja središta masa smeštenih na njoj;
- položaja linija dejstva spoljašnjih opterećenja izazvanih otporom kopanja, što uslovljava zavisnost opterećenja tornja i strele kontratega od ugla nagiba strele rotora u odnosu na horizontalu.

Identifikacija uticaja strele rotora na toranj i strelu protivtega izvedena je za 10 različitih varijanti na osnovu modela prikazanog na sl. 13, korišćenjem algoritma razvijenog u MathCAD-u. Za svaku od analiziranih varijanti, urađen je proračun relevantnih veličina za ceo dijapazon promene ugla nagiba strele rotora (α_{max} = 14,5° pa do α_{min} = –23,42°). Ilustracije radi, na sl. 14 prikazan je dijagram promene sila u zategama strele rotora u zavisnosti od njenog nagiba u odnosu na horizontalu.

Repositioning the bucket wheel beam alters the:
- position of centre of masses mounted on it;
- position of external load lines due to excavation resistance that stipulates dependence of tower and counterweight loads to the angle of inclination to horizontal line of the bucket wheel beam.

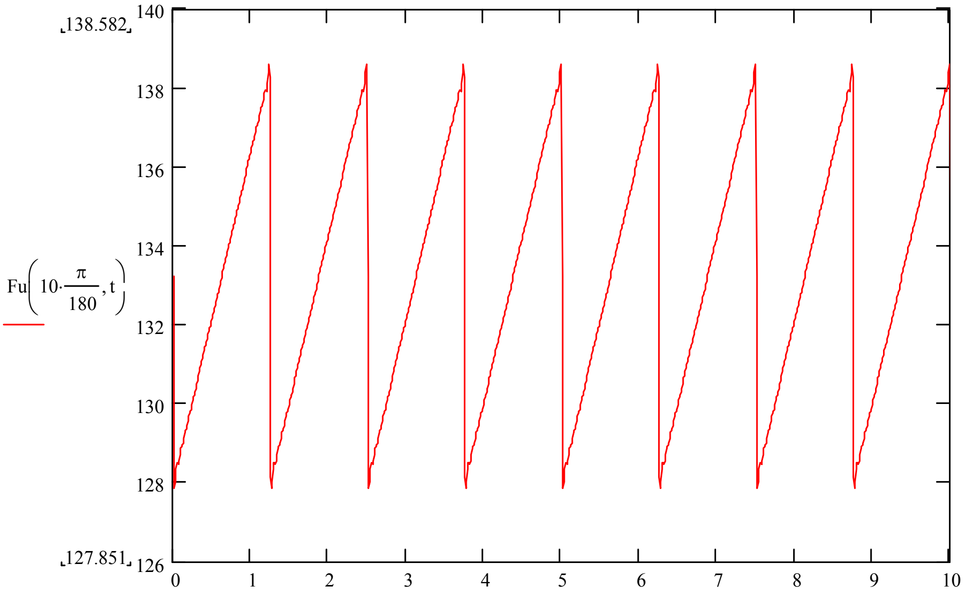
The influence of bucket wheel beam on tower and counterweight beam is identified for 10 different variants based on the model shown in Fig. 13, by using MathCAD. Relevant values are calculated in the whole range of bucket wheel inclination angles (α_{max} = 14.5° to α_{min} = –23.42°), for each analyzed variant. As illustrated, Fig. 14 shows the diagram of force vs. inclination to horizontal line of bucket wheel beam ties.



Slika 14. Zavisnost sila u zategama od položaja strele rotora, /2/
Figure 14. Force in ties dependence on bucket wheel beam position, /2/.

Za razliku od postupka proračuna definisanog standardom DIN 22261-2, koji za uočeni položaj strele rotora daje konstantnu vrednost sila u zategama, razvijeni algoritam omogućava da se u potpunosti odredi spektar opterećenja zatega, odnosno užetnog sistema za dizanje strele rotora, pri zadatom uglu njenog nagiba, sl. 15.

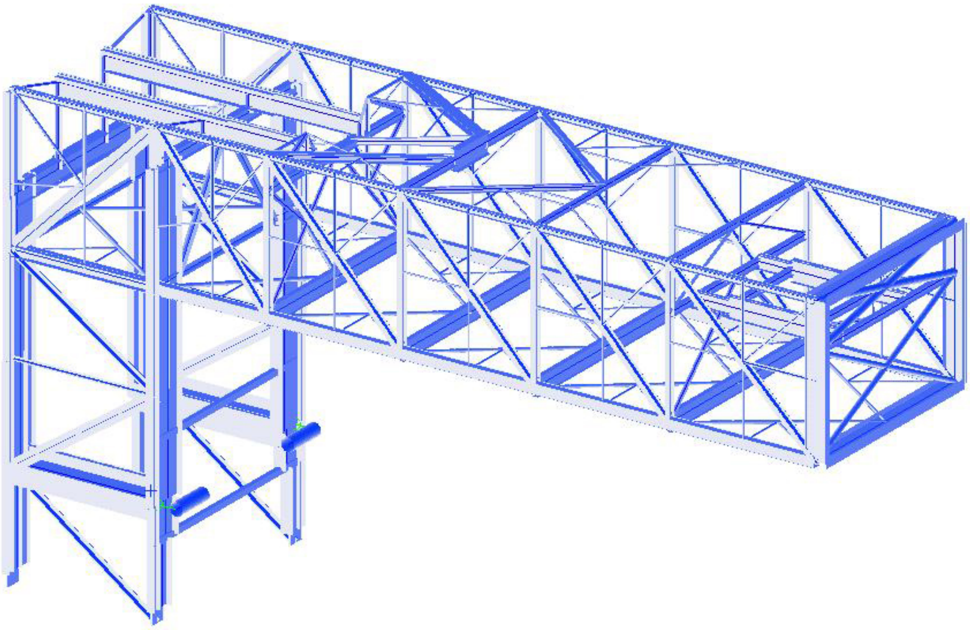
Unlike the calculation procedure defined by standard DIN 22261-2 that gives constant value of forces in ties for an observed position of bucket wheel beam, the developed algorithm enables to define full loading spectra in ties, i.e. the cable system for lifting bucket wheel beam for a specified inclination angle, Fig. 15.



Slika 15. Dijagram promene sile u užadima koturače za dizanje strele rotora, /2/
Figure 15. Diagram of force in cables of tackle for lifting bucket wheel beam, /2/.

Spoljašnje opterećenje se u konstrukciju obrtne platforme uvodi posredstvom zglobnih veza sa tornjem nadgradnje. Da bi se dobila što vernija slika opterećenja strukture obrtne platforme, formiran je konačnoelementni model tornja sa strelom protivtega, sl. 16. On sadrži 209 čvorova, 404 linijska elementa sa dva čvora, kao i dva MPC (*Multi Point Constraints*) elementa. Za definisanje modela korišćena su ukupno 74 poprečna preseka.

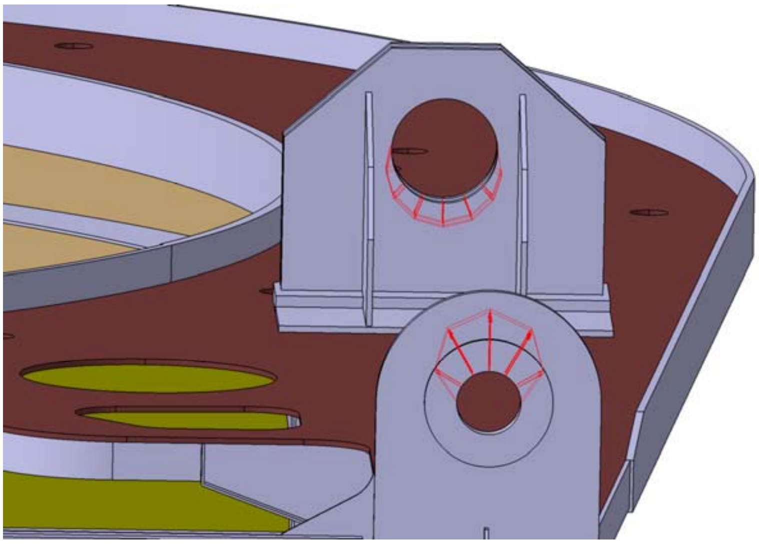
The revolving platform structure is loaded externally through connections hinged with the superstructure tower. In order to get the most realistic presentation of loads on the revolving platform structure, the tower with counterweight beam is modelled by FE, Fig. 16. It contains 209 nodes, 404 beam elements with two nodes, and also two Multi Point Constraint elements. Model defining included 74 cross sections.



Slika 16. Konačnoelementni model strukture tornja sa strelom protivtega, /2/
Figure 16. FE model of tower structure with counterweighting beam, /2/.

Reakcije oslonaca konstrukcije tornja sa strelom protivtega uvedene su kao spoljašnje opterećenje strukture obrtne platforme, sa sinusnom raspodelom po kontaktnim površinama osovinica i uški, sl. 17.

Reactions in the supports of the tower structure with counterweight beam are treated as external loads of the revolving platform structure, with sinusoidal distribution on contact areas of pins and eyes, Fig. 17.



Slika 17. Uvođenje uticaja tornja sa strelom kontratega u konstrukciju obrtne platforme, /2/
Figure 17. Bringing the influence of tower with counterweighting beam in the revolving platform structure, /2/.

NAPONSKO-DEFORMACIONO STANJE ORIGINALNE KONSTRUKCIJE OBRTNE PLATFORME

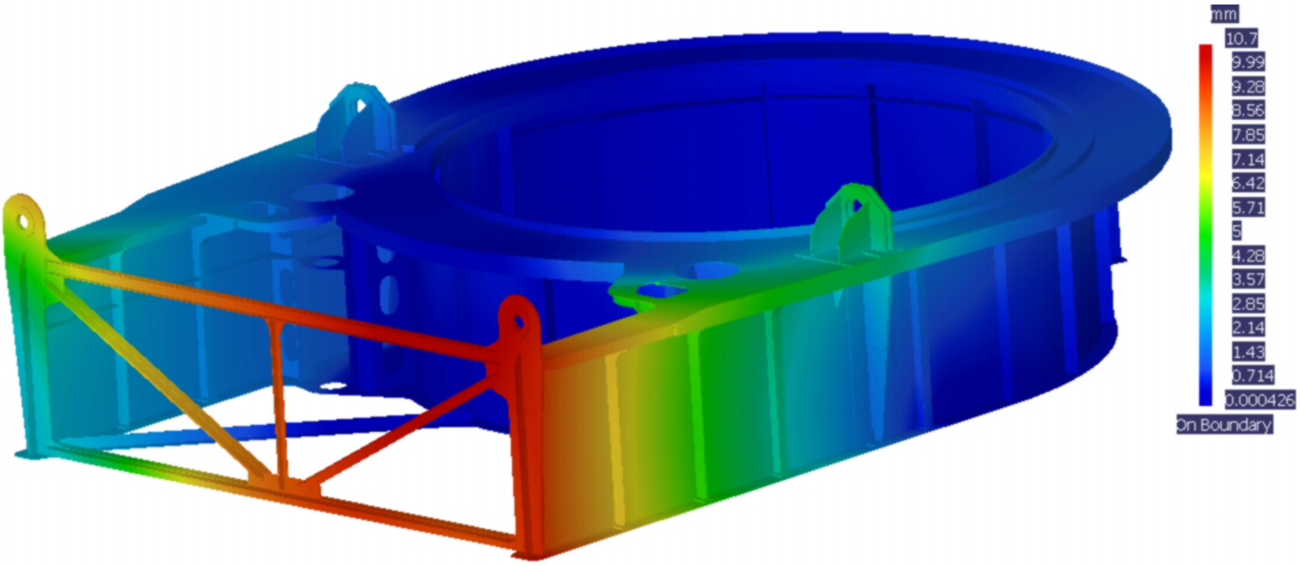
Identifikacija naponsko-deformacionog stanja originalne konstrukcije obrtne platforme izvedena je za 36 različitih slučajeva opterećenja. U nastavku su prezentirani rezultati proračuna za XI i XXIII slučaj opterećenja.

Aksonometrijski izgled deformisane konstrukcije obrtne platforme (faktor uvećanja 100) prikazan je na sl. 18. Najveće pomeranje javlja se u zoni prednje leve uške i iznosi 10,7 mm.

STRESS-STRAIN STATE OF ORIGINAL REVOLVING PLATFORM STRUCTURE

Identification of stress-strain state of original revolving platform structure is done for 36 different load cases. Hereafter, the results are presented for the XI and XXIII case of loading.

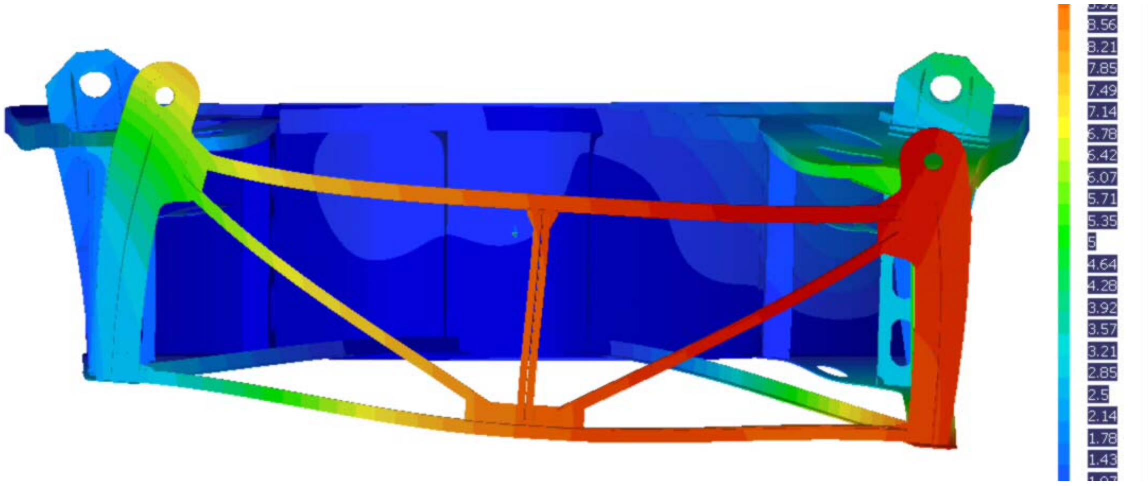
Axonometric view of the deformed revolving platform structure (magnification factor is 100) is shown in Fig. 18. The largest displacement is located in the zone of left front eye and equals 10.7 mm.



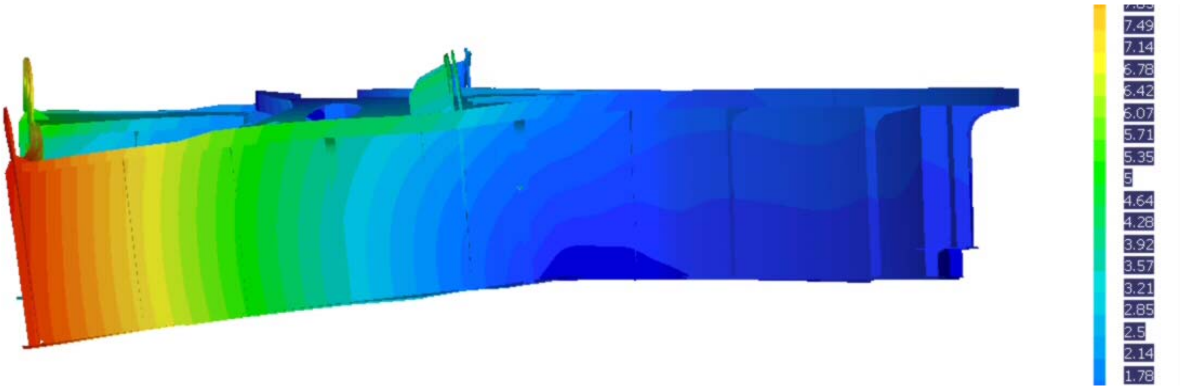
Slika 18. Polje pomeranja originalne konstrukcije obrtne platforme za XI slučaj opterećenja, /2/
Figure 18. Displacement field of original revolving platform structure for XI case of loading, /2/.

Da bi se jasnije sagledala priroda pomeranja konstrukcije, na sl. 19 i 20 prikazani su izgledi deformisane konstrukcije obrtne platforme u globalnim ravnima XY i XZ.

A clearer insight of the nature of structural displacements is shown in Figs. 19 and 20 with a layout of deformed revolving platform structure, in global XY and XZ planes.



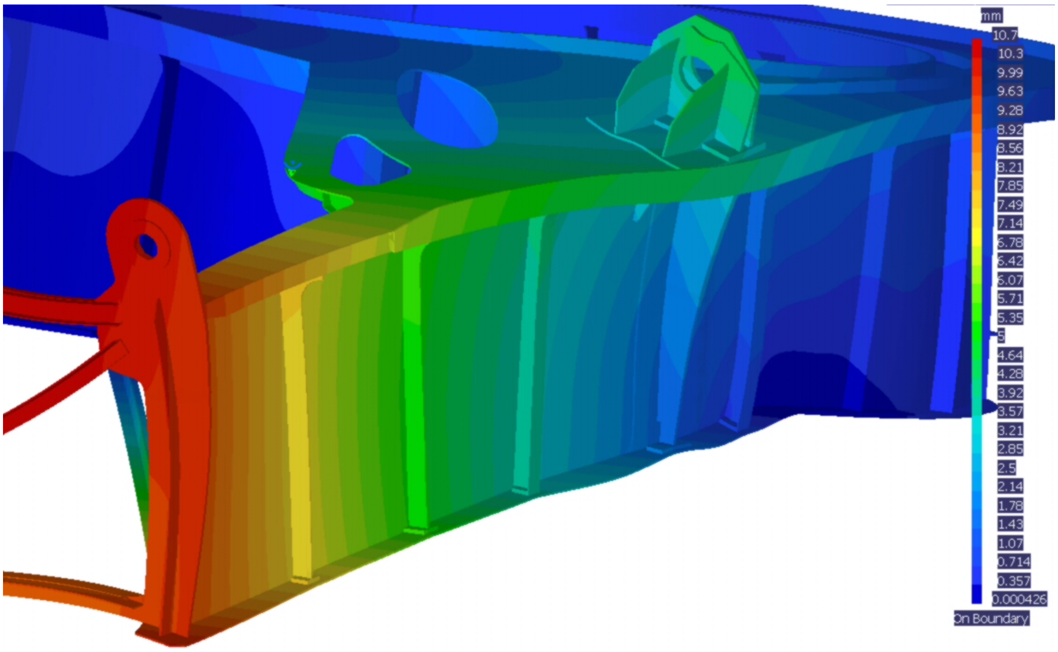
Slika 19. Deformacije originalne konstrukcije platforme u globalnoj ravni XY za XI slučaj opterećenja, /2/
Figure 19. Deformations of original platform structure in global plane XY for the XI loading case, /2/.



Slika 20. Deformacije originalne konstrukcije platforme u globalnoj ravni XY za XI slučaj opterećenja, /2/
Figure 20. Deformations of original platform structure in global plane XY for the XI loading case, /2/.

Izgled leve strane deformisane strukture obrtne platforme (faktor uvećanja 200) prikazan je na sl. 21.

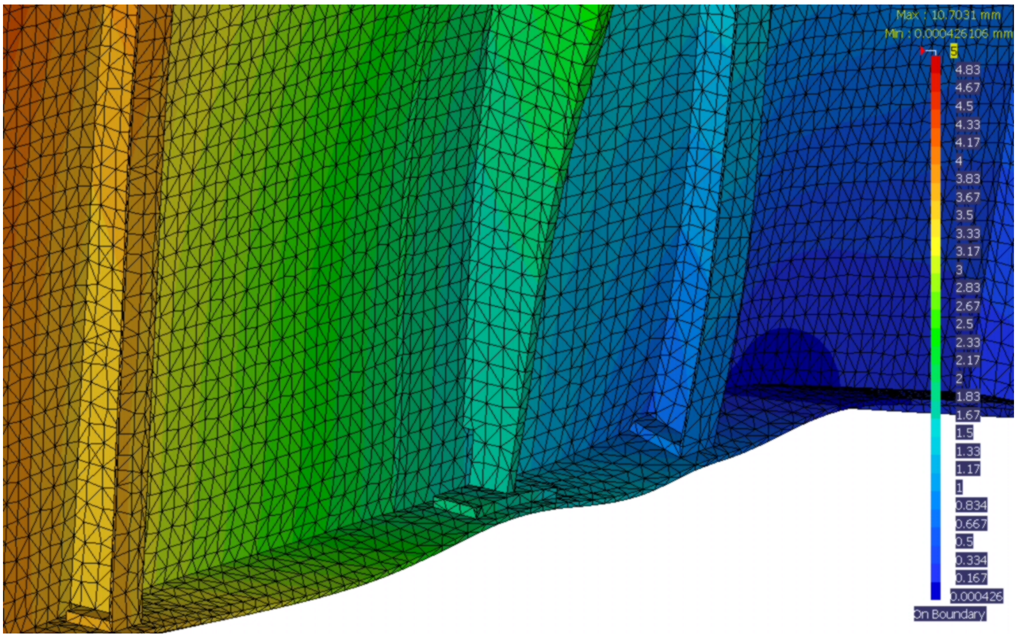
Layout of the left side revolving platform (magnification factor is 200) is shown in Fig. 21.



Slika 21. Izgled deformisane konstrukcije platforme u zoni većih spoljašnjih opterećenja za XI slučaj opterećenja, /2/
Figure 21. Appearance of deformed platform structure in the zone of larger external loads for the XI loading case, /2/.

Detalj deformisane konstrukcije obrtne platforme u zoni pojave prslina i pukotina prikazan je na sl. 22. Na njoj se jasno uočavaju izrazite promene polja pomeranja.

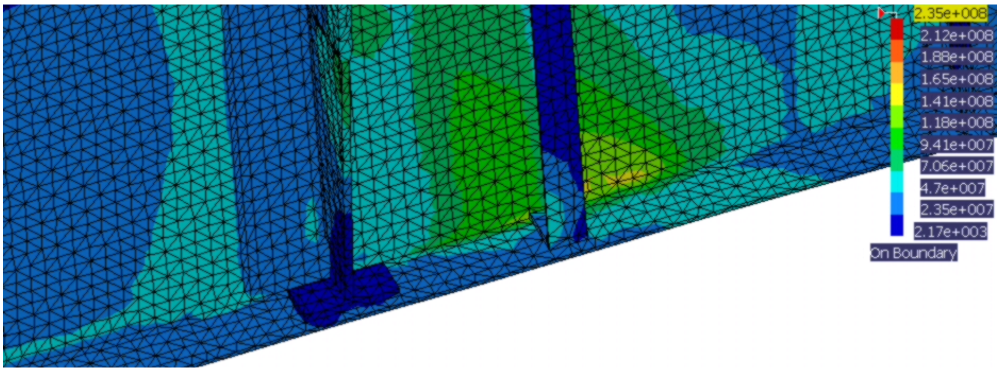
A detail of revolving platform deformed structure in the zone of crack and fracture occurrence is shown in Fig. 22. A significant change in displacement field is observed.



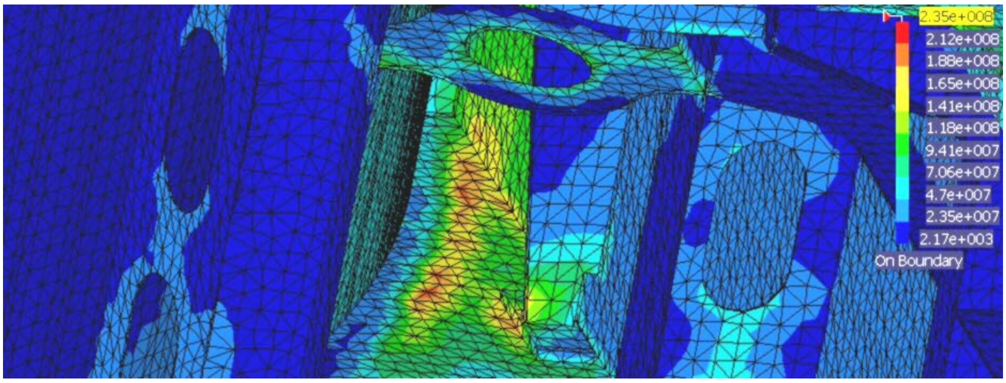
Slika 22. Polje pomeranja u kritičnoj zoni originalne konstrukcije platforme za XI slučaj opterećenja, /2/
Figure 22. Displacement field in critical zone of platform original structure for the XI loading case, /2/.

Distribucija uniaksijalnih napona, određenih prema hipotezi najvećeg deformacionog rada na promeni oblika (hipoteza Huber, Hencky, von Mises), u zoni pojave prslina prikazana je na sl. 23 i 24.

Distribution of uniaxial stresses, defined according to the hypothesis of maximal virtual work for shape changing (hypothesis of Huber, Hencky, von Mises), in the zone of crack occurrence is shown in Figs. 23 and 24.



Slika 23. Naponsko polje u kritičnoj zoni (spolja) originalne konstrukcije platforme za XI slučaj opterećenja, /2/
Figure 23. Field of stress in critical zone (outside) of platform original structure for the XI loading case, /2/.



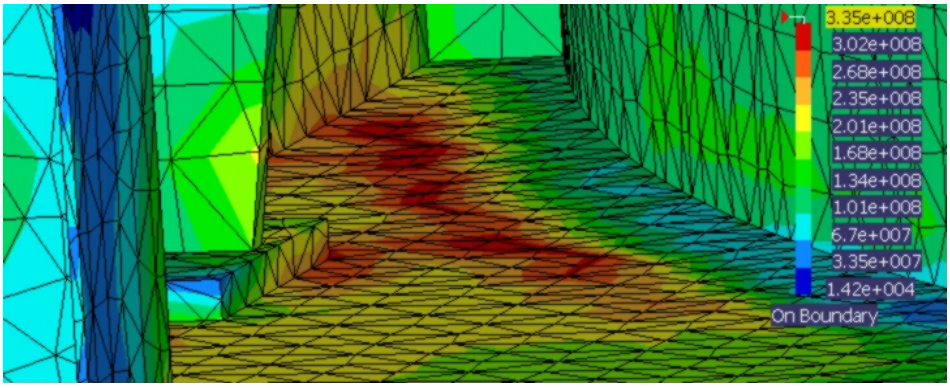
Slika 24. Naponsko polje u kritičnoj zoni (iznutra) originalne konstrukcije platforme za XI slučaj opterećenja, /2/
Figure 24. Field of stress in critical zone (inside) of platform original structure for the XI loading case, /2/.

Maksimalna vrednost napona 23,5 kN/cm^2 javlja se na donjoj ploči, u unutrašnjem delu konstrukcije obrtne platforme.

Izgled naponskog polja u XXIII slučaju opterećenja dat je na sl. 25. Najveća vrednost napona iznosi 33,5 kN/cm^2.

Maximal value of stress equals 23.5 kN/cm^2 in lower plate, in the inner part of revolving platform structure.

Appearance of the stress field for the XXIII loading case is shown in Fig. 25. Maximal stress value is 33.5 kN/cm^2.



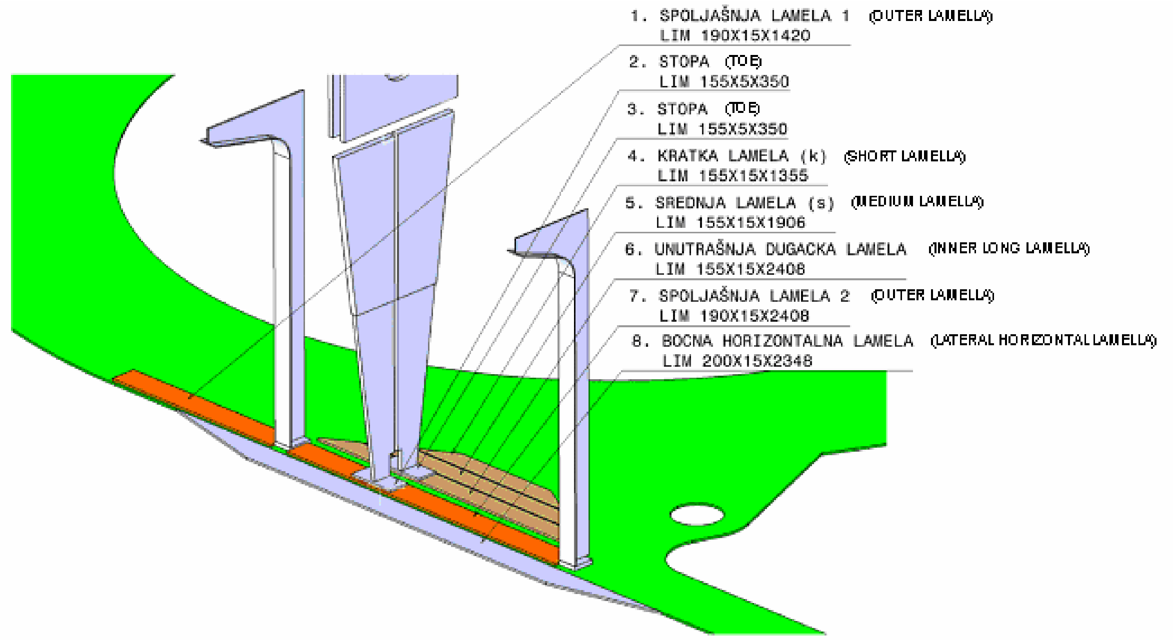
Slika 25. Naponsko polje u kritičnoj zoni (iznutra) originalne konstrukcije platforme za XXIII slučaj opterećenja, /2/
Figure 25. Stress field in critical zone (inside) of platform original structure for the XXIII loading case, /2/.

REKONSTRUKCIJA STRUKTURE OBRTNE PLATFORME

Na osnovu uporedne analize nekoliko varijantnih rešenja rekonstrukcije, pri čemu je kao osnovni kriterijum vrednovanja usvojen zahtev da se ublaže uticaji ulaska podstruktura konzolnih nosača u podstrukturu cilindričnog nosača i nagle promene krutosti u zoni oslonih stopa vertikalnih rebara ispod zadnjih uški, usvojeno je rešenje prikazano na sl. 26. Unutrašnje lamele (pozicije 5, 6 i 7) stepenasto ulaze u formu donje ploče. Ugradnja lamela umesto kontinualne ploče lima obezbeđuje globalno jedinstvo preseka, smanjujući pri tome negativne efekte pojave dvoplatnosti, uz mogućnost da se smanjivanjem debljine lamela koje su bliže osi obrtanja platforme ublaži efekat koncentracije napona.

RECONSTRUCTION OF REVOLVING PLATFORM STRUCTURE

On the basis of comparative analysis of several variants of reconstruction solutions, whereas, the main criterion of evaluation is the requirement for extenuating influences when bringing cantilever girder substructures into the cylindrical girder substructure and rapid change of stiffness in zone of supporting toes on vertical ribs below rear eyes, a solution is chosen and shown in Fig. 26. Inner lamellas (positions 5, 6 and 7) are stepwisely fitted onto the lower plate. Fitting lamellas instead of continual metal sheets enables global section cohesion that reduces negative distortion effects and minimizing stress concentration effects by reducing thickness of lamellas that are closer to the rotation axis of the platform.



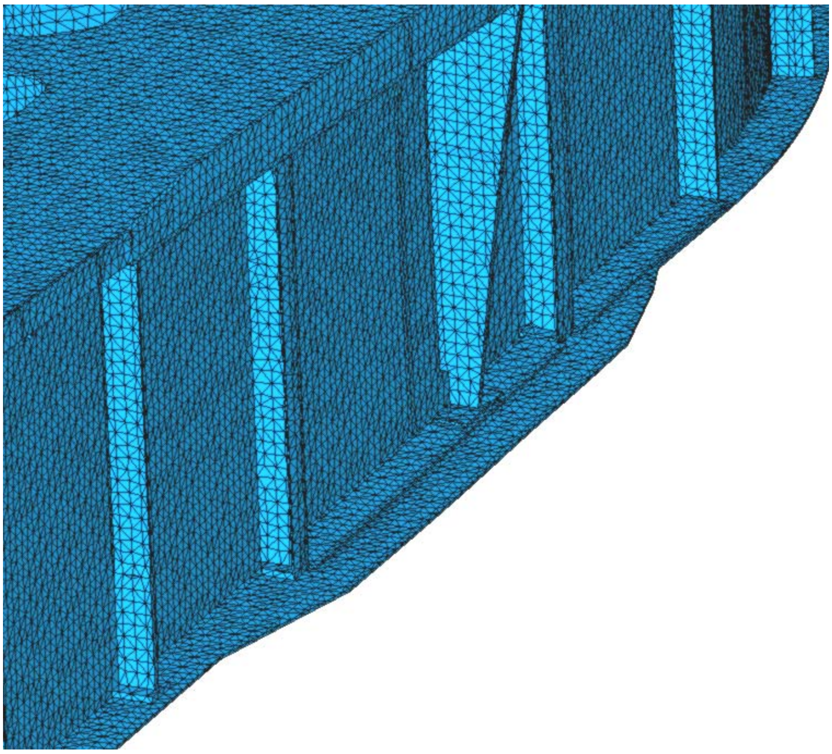
Slika 26. Detalj rekonstruisane obrtne platforme, /2/
Figure 26. Detail of reconstructed revolving platform structure, /2/.

NAPONSKO-DEFORMACIONO STANJE REKONSTRUISANE OBRTNE PLATFORME

Konačnoelementni model rekonstruisane konstrukcije obrtne platforme formiran je na način opisan u tački KONAČNOELEMENTNI MODEL ORIGINALNE KONSTRUKCIJE OBRTNE PLATFORME ovog rada. Detalj modela u zoni pojave prslina prikazan je na sl. 27.

STRESS-STRAIN STATE OF RECONSTRUCTED REVOLVING PLATFORM STRUCTURE

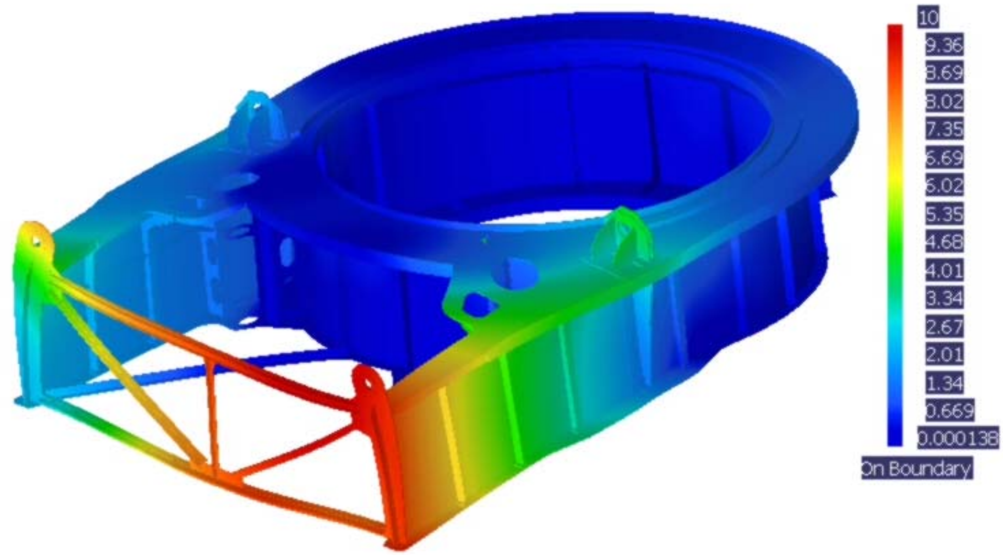
The FE model of the reconstructed revolving platform structure is formed in the manner described in the section FINITE ELEMENT MODEL OF ORIGINAL STRUCTURE OF REVOLVING PLATFORM of this paper. Model detail in zone of crack occurrence is shown in Fig. 27.



Slika 27. Konačnoelementna mreža rekonstruisane platforme u kritičnoj zoni, /2/
Figure 27. FE mesh of reconstructed platform structure in the critical zone, /2/.

Aksonometrijski izgled polja deformacija konstrukcije obrtne platforme (faktor uvećanja 100) u XI slučaju opterećenja, prikazan je na sl. 28. Najveće pomeranje se javlja u zoni prednje leve uške i iznosi 10.0 mm.

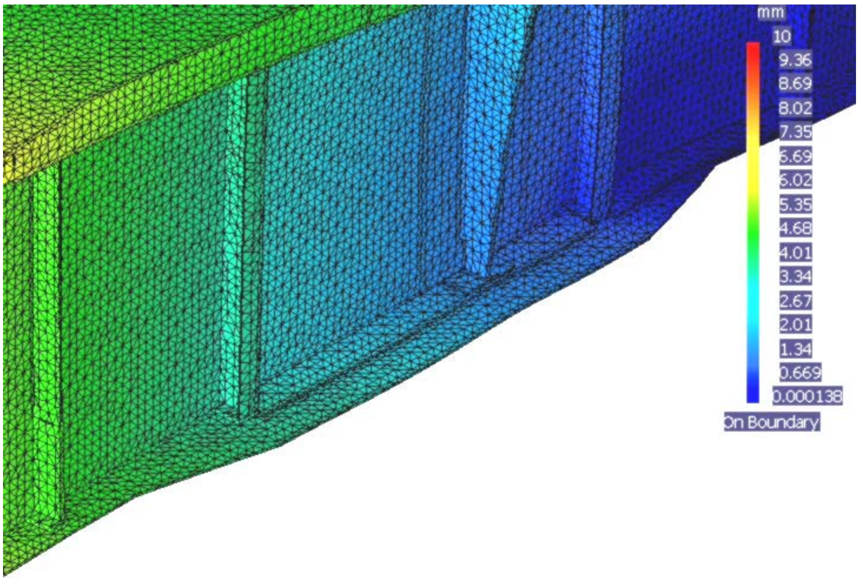
The axonometric layout of the deformation field in the revolving platform structure (magnification factor is 100) in the XI loading case is shown in Fig. 28. The largest displacement is in zone of front left eye and equals 10.0 mm.



Slika 28. Polje pomeranja rekonstruisane obrtne platforme za XI slučaj opterećenja, /2/
Figure 28. Displacement field of reconstructed revolving platform structure for the XI loading case, /2/.

Izgled deformisane konstrukcije u kritičnoj zoni prikazan je na sl. 29.

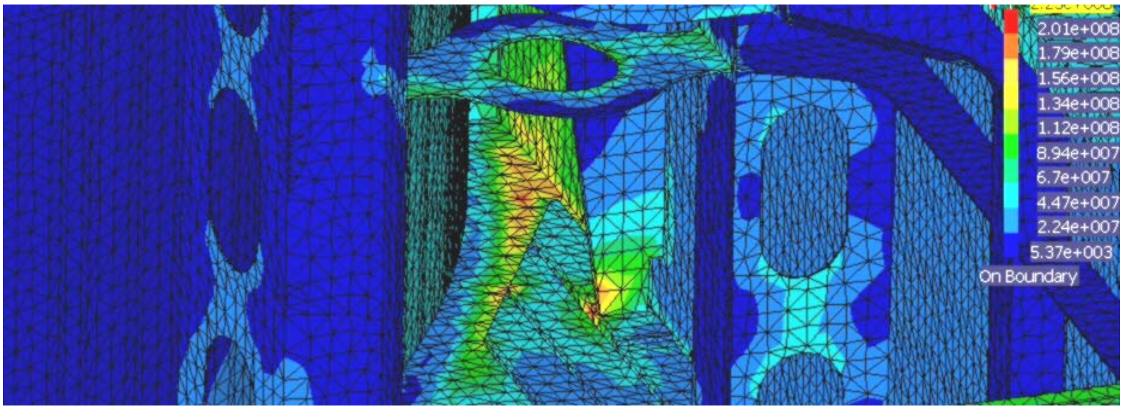
The layout of the deformed structure in the critical zone is shown in Fig. 29.



Slika 29. Polje pomeranja u kritičnoj zoni rekonstruisane platforme za XI slučaj opterećenja, /2/
Figure 29. Displacement field in critical zone of reconstructed platform structure for the XI loading case, /2/.

Maksimalna vrednost napona (hipoteza *Huber, Hencky, von Mises*) u zoni pojave prslina, sl. 30, iznosi 20,0 kN/cm^2.

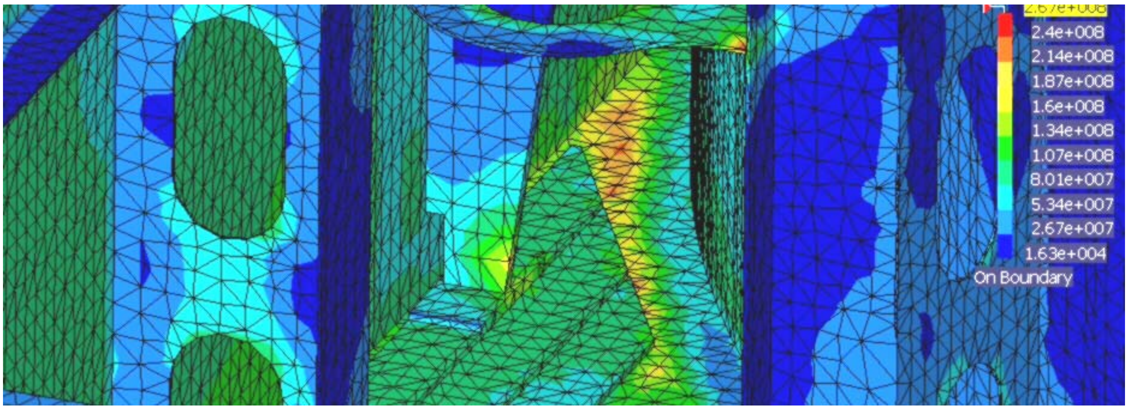
Maximal stress (hypothesis *Huber, Hencky, von Mises*) in zone of crack occurrence, Fig. 30, equals 20.0 kN/cm^2.



Slika 30. Naponsko polje u kritičnoj zoni (iznutra) rekonstruisane platforme za XI slučaj opterećenja, /2/
Figure 30. Stress field in critical zone (inside) of reconstructed platform structure for the XI loading case, /2/.

U XXIII slučaju opterećenja maksimalna vrednost napona u kritičnoj zoni je 25,5 kN/cm^2, sl. 31.

The maximal stress in the critical zone of XXIII loading case is 25.5 kN/cm^2, Fig. 31.



Slika 31. Naponsko polje u kritičnoj zoni (iznutra) rekonstruisane platforme za XXIII slučaj opterećenja, /2/
Figure 31. Stress field in critical zone (inside) of reconstructed platform structure for the XXIII loading case, /2/.

ZAKLJUČAK

Konačnoelementni model konstrukcije, formiran tako da u svim detaljima odgovara stvarnoj konstrukciji, uz odgovarajuću analizu opterećenja, omogućava:

- kreiranje rešenja rekonstrukcije specifičnih i složenih konstrukcija sa što manjim zahvatima, uz istovremeno ostvarivanje zahteva vezanih za čvrstoću;
- definisanje tehnologija izvođenja sanacije i rekonstrukcije u terenskim uslovima.

Rekonstrukcijom obrtne platforme–suptilnim ojačanjem donje ploče u zoni zadnjih stubova, ostvareni su sledeći efekti:

- značajno niži nivo naponskih stanja–od približno 15% (XI slučaj opterećenja) do oko 24% (XXIII slučaj opterećenja);
- znatno blaža promena polja deformacija u kritičnoj zoni, sl. 22 i 29, a da pri tome nije ugrožena dinamička stabilnost bagera, što je verifikovano odgovarajućom modalnom analizom.

Primenom postupka čiji je kratak prikaz dat u ovom radu, tokom 2005. godine izvršena je sanacija i rekonstrukcija obrtnih platformi dva bagera TAKRAF SRs 1200 × 24/4 (400 kW) + VR u JP RB „Kolubara“. Prema izveštajima korisnika, pomenute mašine su nakon rekonstrukcije otkopale više od 5 000 000 m^3 otkrivke. Vizuelnom kontrolom rekonstruisanih delova obrtnih platformi nisu konstatovane pojave prslina ili pukotina.

Činjenica da nabavka nove opreme za površinsku eksploataciju uglja iziskuje znatna materijalna sredstva, upućuje na zaključak da revitalizacija, shvaćena u širem smislu, /5/, predstavlja najracionalniji put očuvanja i podizanja performansi teške rudarske mehanizacije u našoj zemlji. Saglasno izloženom, iskustva stečena rešavanjem problema sanacije i rekonstrukcije rotornih bagera predstavljaju solidnu osnovu za izradu projekata revitalizacije razmatrane klase mašina.

Ovaj rad predstavlja deo istraživanja u okviru projekta tehnološkog razvoja TR 6368 "Unapređenje performansi pogonskih sistema rotornih bagera", podržan od strane Ministarstva nauke i zaštite životne sredine Republike Srbije.

CONCLUSION

The FE model of the structure is formed so that it corresponds in full detail to the real structure, and appropriate analysis of loads enables:

- to develop a reconstruction solution for specific and complex structures with least interventions possible and fulfilment of strength requirements;
- defining the technology for repair and reconstruction at in-situ working conditions.

The reconstruction of the revolving platform structure–by subtle strengthening the lower plate in the zone of rear columns, has resulted in the following effects:

- considerably lower stress state levels–from about 15% (XI loading case) up to about 24% (XXIII loading case);
- significantly smoother changes in the deformation field in the critical zone, Figs. 22 and 29, yet not jeopardizing dynamic stability of the BWE which is verified by adequate modal analysis.

By applying the procedure, discussed briefly in this paper, during year 2005, the repair and reconstruction of revolving platform structures for two BWE TAKRAF SRs 1200 × 24/4 (400 kW) + VR in the Public Agency Mining Open Pit “Kolubara” was undergone. According to reports by BWE users, these machines have excavated more than 5 000 000 m^3 of barren soil after reconstruction. Visual inspection of reconstructed platform structural parts has not detected any cracks or fracturing occurrences.

The fact that the purchase of new equipment for open pit coal exploitation would impose significant costs has lead to the conclusion that revitalisation, understood in a broader sense, /5/, is the most cost effective way of preserving and improving performance of heavy mining mechanization in our country. Pursuant to the displayed, experiences gained in solving BWE repair and reconstruction problems are a reliable basis for developing projects for the revitalisation of the discussed class of machinery.

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