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UNAPREĐENJE INDUSTRIJSKE BEZBEDNOSTI KRANSKIH KABINA

INDUSTRIAL SAFETY IMPROVEMENT OF CRANE CABINS

Originalni naučni rad / Original scientific paper
UDK /UDC: 331.433:629.364.1.042.2
Rad primljen / Paper received: 20.07.2015

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Ključne reči

- kranska kabina
- bezbednost i zdravlje na radu
- metoda konačnih elemenata
- ergonomska prilagođenost
- prototip

Izvod

Kranovi značajno doprinose efikasnom radu, ali su potencijalna opasnost i uzrok velikih gubitaka imovine, kao i značajnog broja smrtnih slučajeva. Današnji kranovi ne zadovoljavaju potrebe većine operatera, što utiče na smanjenje njihove bezbednosti i zdravlja na radu. Stoga je cilj ovog rada da istraži mogućnosti unapređenja bezbednosti kranskih kabina. Sprovedeno je istraživanje na uzorku operatera, koji upravljaju iz kabina kranova različitih proizvođača, sa zaključkom da je potrebno projektovati prototip kabine koji bi omogućio poboljšanje ergonomskih karakteristika, uz istovremeno povećanje bezbednosti procesa. Primenom metode konačnih elemenata i programa KOMIPS modeliran je nov prototip kabine. Razvijena kranska kabina je održiv proizvod sa manje angažovanih resursa, zahvaljujući umanjenju mase i povećanju prilagodljivosti čoveku.

UVOD

Jedan od ključnih faktora i preduslova za dugotrajni opstanak i konkurentnost proizvoda na evropskom tržištu je industrijska bezbednost, na šta ukazuju često korišćene fraze kao što je „ako mislite da je bezbednost skupa, probajte da imate nesreću na radnom mestu“ /1/. Kranovi značajno doprinose efikasnom napredovanju posla, kada se njima pravilno upravlja, ali takođe imaju potencijal da prouzrokuju ogromne gubitke imovine kao i značajan broj smrtnih slučajeva, pri čemu treba istaći da rizik od gubitka nije ograničen samo na operatere kranova, /2/. Mnoge procedure u okviru razvojnog procesa kabina krana danas su zasnovane na pojedinačnim iskustvima proizvođača i iskustvenim smernicama, pa nije iznenađujuće da ne zadovoljavaju potrebe većine operatera, /3/.

Prema OSHA istraživanju iz 1996. identifikovana su 502 smrtna slučaja vezana za kranove, u 479 situacija u periodu između 1984. i 1994. godine, gde je stopa smrtnosti bila 1,4 na 1000 operatera za 45 godina radnog veka, /2, 4/.

Prema referenci /5/ kranovi su učestvovali u 306 smrtnih slučajeva, što predstavlja 16,1% svih smrtnih slučajeva, u periodu između 1980. i 1992. godine, odnosno, stopu smrtnosti od 0,34 na 100.000 radnika.

Keywords

- crane cabin
- work safety
- finite element method
- ergonomic adaptability
- prototype

Abstract

Cranes significantly contribute to efficient work progress but also have a great potential to cause large life and financial losses. Cranes today do not meet the needs of large proportion of operators, therefore making them even less safe to operate. Hence, the aim of this paper is to explore possibilities to increase crane cabin safety. Research is conducted on the sample of crane operators who operate cranes of different manufacturers, resulting in the conclusion that there is a need to design a cabin prototype that would improve ergonomic characteristics of the cabin while increasing process safety. With the finite element method and KOMIPS software new cabin prototype is designed. The new crane cabin represents a sustainable product with less resource usage due to decrease of cabin mass and increase of adaptability to the human operator.

INTRODUCTION

One of the key factors and prerequisites for long-term product presence and competitiveness on the European market is industrial safety, which is indicated by frequently used phrases such as ‘if you think safety is expensive, try having an accident in the workplace’ /1/. Cranes significantly contribute to efficient work flow, when operated properly, but also have the potential to cause considerable property losses and a large number of fatalities, wherein it should be pointed out that the risk from losses is not only limited to crane operators, /2/. Numerous procedures within the development process of crane cabins today are based on individual manufacturer experiences and guidelines, thus it is no surprise that they do not satisfy the needs of most operators, /3/.

According to the OHSA research from 1996, 502 crane-related fatalities have been identified, 479 of which were in the period between 1984 and 1986, where the mortality rate was 1.4 per 1000 operators for a working life of 45 years /2, 4/. According to reference /5/, cranes were involved in 306 fatalities, which is 16.1% of all fatalities in the period between 1980 and 1992, i.e. a mortality rate of 0.34 for every 100 000 workers.

CCRT (*Centre for Construction Research and Training*) na osnovu podataka BLS-a (*Bureau of Labor Statistics*) identifikuje 323 smrtna slučaja u 307 nesreća sa kranovima, u periodu od 1992. do 2006. godine, što u proseku iznosi 22 smrtna slučaja godišnje. Bilo je i 12 nesreća sa višestrukim smrtnim ishodom, /6/.

Prema Surudi i saradnicima /4/ glavni uzroci nesreća su: udar struje (39%), montaža/demontaža krana (12%), lom konstrukcije/deformacija strele (8%), pad/prevrtanje krana (7%), otkaz opreme (7%), preopterećenje (4%), udar tereta u pokretu (4%), nesreće vezane za ručna podizanja (4%), itd. Ovi rezultati se poklapaju sa ostalim istraživanjima koja su takođe došla do zaključka da je strujni udar glavni uzrok nesreća. Prema CPRW, /6/, od 323 smrtna slučaja vezana za kranove, 102 nesreće su bile uzrokovane napajanjem (32%), 68 je vezano za lom konstrukcije (21%) i 59 je uzrokovano deformisanom strelom (18%).

U istraživanju podataka iz BLS-a, /6/, navodi se da četiri tipa kranova najčešće učestvuju u nesrećama sa smrtnim ishodom. Od 307 nesreća, u 216 (71%) su učestvovale autodizalice. U 16 nesreća sa smrtnim ishodom su učestvovale građevinske stubne dizalice (5%), u 13 lučke dizalice (4%), i u 12 su učestvovale mosne dizalice (4%).

Neitzel i saradnici, /2/, ističu da proizvođači kranova moraju projektovati kranove kojima je moguće bezbedno upravljati, od strane adekvatno obučenog operatera krana, te da moraju biti ispunjeni svi standardi vezani za bezbednost i projektovanje. Ovde treba posebno istaći najnovije preporuke OSHA od 9. avgusta 2010. godine, u oblasti *'Cranes and Derricks in Construction'*, /7/.

Zbog svega navedenog, ovaj rad ima za cilj da istraži mogućnosti unapređenja industrijske bezbednosti kranskih kabina.

ISTRAŽIVANJE POTREBA OPERATERA KRANOVA

Od usklađenosti antropometrijskih karakteristika operatera sa dimenzijama kabine dizalice, kao i sa dimenzijama i položajem opreme u kabini, zavisi veći broj faktora, koji su od značaja za projektanta. Ovi faktori se mogu podeliti u tri osnovne kategorije. U prvu kategoriju spadaju faktori koji se odnose na efekte koje antropometrijska neusklađenost kabine (sa opremom u njoj) ima na operatera. U drugu kategoriju spadaju faktori koji se odnose na efekte koje antropometrijska neusklađenost kabine ima na radni učinak i finansijske rezultate kompanije. U treću kategoriju spadaju faktori koji se odnose na efekte koje antropometrijska neusklađenost kabine ima na bezbednost.

U cilju identifikacije problema u okviru postojećih projektantskih rešenja kabina dizalica, kao i prikupljanja informacija koje bi se mogle koristiti kao preporuke za projektovanje kabina dizalica sa antropometrijske tačke gledišta, sprovedeno je istraživanje na uzorku operatera kranova koji upravljaju iz kabina različitih proizvođača. Rezultati u tabeli 1 pokazuju ocene karakteristika kabina, /8/, preko procentnih indeksa adekvatnosti, a koje je moguće kategorisati u sledeće grupe:

1. Interakcije operatera (tabela 1, karakteristike 1-3)
2. Sigurnosne (tabela 1, karakteristike 4 i 5)
3. Ergonomske (tabela 1, karakteristike 6-8)

Based on the data from BLS (Bureau of Labor Statistics) CCRT (The Center for Construction Research and Training) identified 323 fatalities in 307 accidents with cranes, between 1992 and 2006, which is an average of 22 fatalities per year. Twelve of these accidents involved multiple fatalities, /6/.

According to Suruda et al., /4/, main causes of accidents are: electric shocks (39%), mounting/dismounting of cranes (12%), structural fracture/crane arm deformation (8%), falling/capsizing of the crane (7%), equipment failure (7%), overloading (4%), impact of load in motion (4%), accidents related to manual lifting (4%). These results comply with others which have also reached the conclusion that electric shock is the main cause of accidents. According to CCRT, /6/, out of 323 crane related accidents, 102 were caused by power supply (32%), 68 were related do structural fracture (21%) and 59 were caused by a deformed crane arm (18%).

Research data from BLS, /6/, mentions that four types of cranes are typically involved in fatal accidents. Out of 307 accidents, 216 (71%) involved auto-cranes. 16 (5%) fatal accidents involved construction column cranes, and 13 (4%) involved harbour cranes, whereas 12 (4%) involved bridge cranes.

Neitzel et al., /2/, pointed out that crane manufacturers must design cranes which can be operated safely by adequately trained crane operators, as well as that all safety and design standards must be met. Here, latest OHSA recommendations from August 9, 2010, in the area 'Cranes and Derricks in Construction', /7/, should be especially emphasized.

Due to all mentioned above, this paper is written with the goal to research the possible improvements of industrial safety of crane cabins.

RESEARCH OF CRANE OPERATERS' NEEDS

Conformity of anthropometrical characteristics of the operator with crane cabin dimensions, as well as dimensions and position of equipment inside the cabin, affects a large number of factors, significant for the designer, which can be divided into three basic categories. The first category includes factors related to effects of anthropomorphic nonconformity of the cabin (including the equipment) has on the operator. Second category includes factors related to effects the anthropomorphic non-conformity of the cabin has on work performance and financial results of the company. Third category includes factors related to effects the anthropomorphic non-conformity of the cabin has on safety.

For the purpose of identifying problems within existing designer solutions for crane cabins, as well as for gathering information which could be used as recommendations for designing crane cabins from the anthropomorphic standpoint, an investigation is conducted on a sample of crane operators who worked in cranes made by various manufacturers. Results in Table 1 show the evaluation of cabin characteristics, /8/, in form of percent adequacy indexes, which can be categorized into following groups:

1. Operator interactions (Table 1, characteristics 1-3)
2. Safety (Table 1, characteristics 4 and 5)
3. Ergonomic (Table 1, characteristics 6-8)

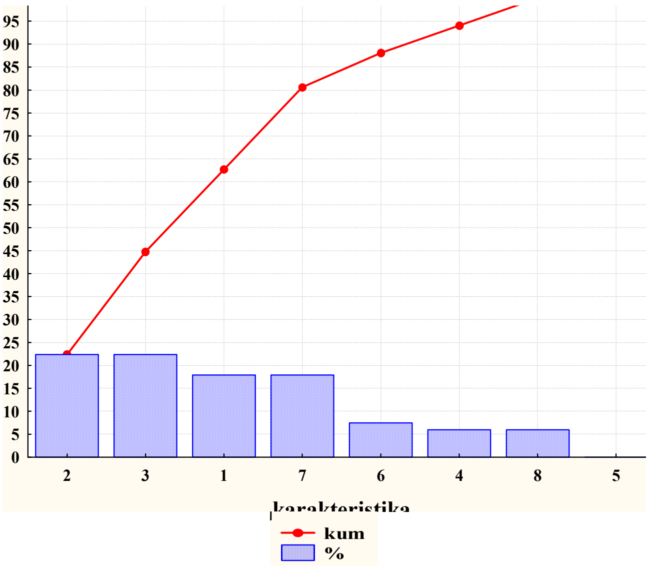
Tabela 1. Ocena karakteristika preko procentnih indeksa

	Karakteristika	Luela	Libherr	Mc Gregor	Krupp	Tsuji	MHI
1	Razumljivost signalizacije	0,8	0,8	0,8	0,4	0,2	0,2
2	Razumljivost simbola	0,25	1	1	0,25	0,5	0,25
3	Vidljivost sadržaja displeja	1	0,75	0,5	0,25	0,25	0,25
4	Vidljivost tereta, preglednost okoline	0,8	0,6	0,6	0,8	0,6	0,2
5	Fiksni delovi u kabini	0,75	1	1	1	0,75	1
6	Veliki i stacionarni delovi	1	1	1	0,75	0,75	0,75
7	Logični i ergo-nomski indikatori i regulatori	0,8	0,4	0,4	0,4	0,2	0,2
8	Prilagodljiv radni položaj	1	0,4	0,4	0,8	0,4	0,2
	Zbirni indeks	6,4	5,95	5,7	4,65	3,65	3,05

Table 1. Evaluation of characteristics using percent indexes.

	Characteristics	Luela	Libherr	Mc Gregor	Krupp	Tsuji	MHI
1	Signalisation intelligibility	0.8	0.8	0.8	0.4	0.2	0.2
2	Symbol intelligibility	0.25	1	1	0.25	0.5	0.25
3	Visibility of display contents	1	0.75	0.5	0.25	0.25	0.25
4	Visibility of load and surroundings	0.8	0.6	0.6	0.8	0.6	0.2
5	Fixed parts in the cabin	0.75	1	1	1	0.75	1
6	Large and stationary parts	1	1	1	0.75	0.75	0.75
7	Logical and ergo-nomic indicators and regulators	0.8	0.4	0.4	0.4	0.2	0.2
8	Adjustable working position	1	0.4	0.4	0.8	0.4	0.2
	Total index	6.4	5.95	5.7	4.65	3.65	3.05

Rezultati Pareto analize za primer kabine proizvođača Krupp, prikazani na sl. 1, pokazuju da su karakteristike koje najmanje odgovaraju operaterima razumljivost simbola i vidljivost sadržaja displeja (23,39%). Naredne dve neodgovarajuće karakteristike po rangu su razumljivost signalizacije i logično i ergonomski ispravno postavljeni indikatori i regulatori (17,91%). Navedene četiri karakteristike predstavljaju 80,6% karakteristika koje ne odgovaraju (tabela 2). Zatim slede veliki i stacionarni delovi, vidljivost tereta i bližeg okruženja, prilagodljivost radnog položaja i fiksirani delovi u kabini koji zajedno učestvuju sa 19,4%. Stoga se može zaključiti da Krupp kranske kabine ne odgovaraju radu operatera, te da postoji potreba za njihovim redizajnom. Slični rezultati, sa istim krajnjim zaključkom su dobijeni i za kabine drugih analiziranih proizvođača.



Slika 1. Pareto analiza za karakteristike kabina Krupp

Results of the Paretto analysis for the example with cabin manufacturer Krupp, given in Fig. 1, show that the characteristics least suitable to the operators are symbol intelligibility and display content visibility (23.39%). The following two inadequate characteristics include signalization intelligibility and logical and ergonomically positioned indicators and regulators (17.91%). The above four characteristics represent 80.6% of the inadequate characteristics (Table 2). These are followed by large and stationary parts, load and immediate surroundings visibility, adaptability of working position and fixed parts in the cabin, with a total share of 19.4%. Thus, it can be concluded that Krupp crane cabins do not conform to operator's work and that there is a need for their redesigning. Similar results with the same final conclusion are obtained for cabins of other manufacturers.

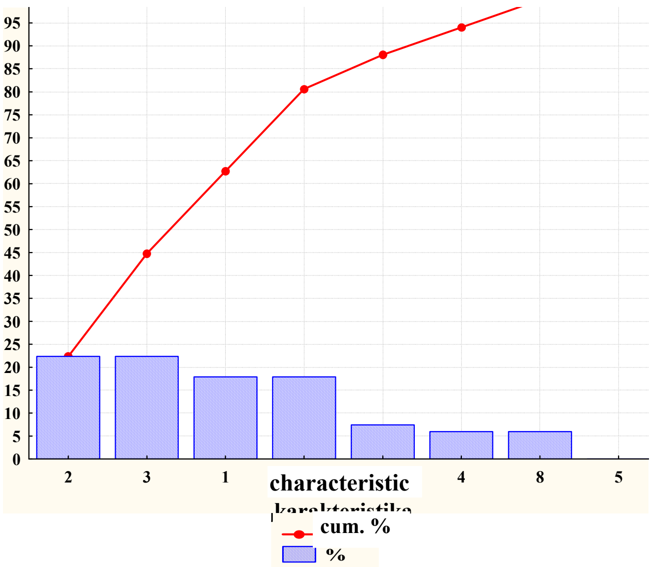


Figure 1. Paretto analysis of characteristics of a Krupp crane cabin

Tabela 2. Rangiranje karakteristika kranskih kabina Krupp

	Rangiranje karakteristika kranskih kabina Krupp	Indeks	%	kumulativno%
2	Razumljivi simboli	0,75	22,388	22,388
3	Vidljivost sadržaja displeja	0,75	22,388	44,776
1	Razumljivi signali	0,6	17,910	62,686
7	Logični i ergonomski indikatori i regulatori	0,6	17,910	80,597
6	Veliki i stacionarni delovi	0,25	7,463	88,060
4	Vidljivost tereta i bližeg okruženja	0,2	5,970	94,030
8	Prilagodljivost radnog položaja	0,2	5,970	100
5	Fiksirani delovi u kabini	0	0	100

Na osnovu rezultata istraživanja baziranog na ocenama operatera kranova o uticaju karakteristika postojećih kabina na efikasnost upravljanja kranovima i bezbednost i zdravlje na radu, zaključeno je da je potrebno projektovati prototip kabine koji bi omogućio poboljšanje ergonomskih karakteristika kabine, uz istovremeno povećanje bezbednosti procesa.

STATIČKI I DINAMIČKI PRORAČUN KONSTRUKCIJE PROTOTIPA KABINE

Prostor potreban rukovaocu kabine u kome je moguće eliminisati nedostatke kritičnih karakteristika u postojećim kranskim kabinama iznosi 1095×1150×1865 mm /3/. Shodno tome, primenom metode konačnih elemenata korišćenjem programa KOMIPS - kompjutersko modeliranje i proračun struktura, /9/, sprovedeno je modeliranje novog prototipa kabine uz primenu statičkog i dinamičkog proračuna, na osnovu čega su dobijene optimalne karakteristike novog prototipa kranske kabine.

Model za proračun konstrukcije prototipa kranske kabine

Geometrija proračunskog modela prototipa konstrukcije kabine sa brojevima čvorova i konačnih elemenata grede prikazana je na sl. 2 i 3. Model ima 65 čvornih tačaka i 111 konačnih elemenata tipa grede.

Konstrukcija prototipa kabine ima sledeće karakteristike: površina stakla je 8,2 m^2; masa čelične konstrukcije kabine 470 kg; a masa operatera i stolice 150 kg.

Na sl. 4 i 5 prikazani su modeli za statički i dinamički proračun čelične konstrukcije prototipa kabine.

Statički proračun

Rezultati statičkog proračuna prikazani su na sl. 6-7. Rezultati statičkog proračuna konstrukcije prototipa kabine ukazuju na izuzetno malu vrednost deformacija (ugiba) svih tačaka modela konstrukcije u svim pravcima, na izuzetno nisku vrednost naponskog stanja u svim elementima modela konstrukcije prototipa kabine, i istovremeno na činjenicu da je krutost konstrukcije prototipa kabine izuzetno velika.

Table 2. Ranking of characteristics of a Krupp crane cabin.

	Ranking of characteristics of a Krupp crane cabin	Index	%	cumulative %
2	Intelligible symbols	0.75	22.388	22.388
3	Visibility of display contents	0.75	22.388	44.776
1	Intelligible signals	0.6	17.910	62.686
7	Logical and ergonomic indicators and regulators	0.6	17.910	80.597
6	Large and stationary parts	0.25	7.463	88.060
4	Visibility of load and immediate surroundings	0.2	5.970	94.030
8	Working position adaptability	0.2	5.970	100
5	Fixed parts in the cabin	0	0	100

From the results of research based on operators' evaluation of the effects of existing crane cabins on their effective operating and safety and health at work, it is concluded that a prototype cabin needs to be designed, which would enable improved ergonomic characteristics of the cabin, while simultaneously increasing the safety of the process.

STATIC AND DYNAMIC CALCULATION OF THE CABIN PROTOTYPE STRUCTURE

The space necessary for the cabin operator which would eliminate the drawbacks of critical characteristics in existing crane cabins is 1095×1150×1865 mm, /3/. Accordingly, by applying the finite element method using KOMIPS (Computer modelling and structural calculation) software, /9/, the modelling of a new cabin prototype is performed, including both static and dynamic calculations, based on which optimal characteristics of the new crane cabin prototype are obtained.

Model for calculating the prototype crane cabin

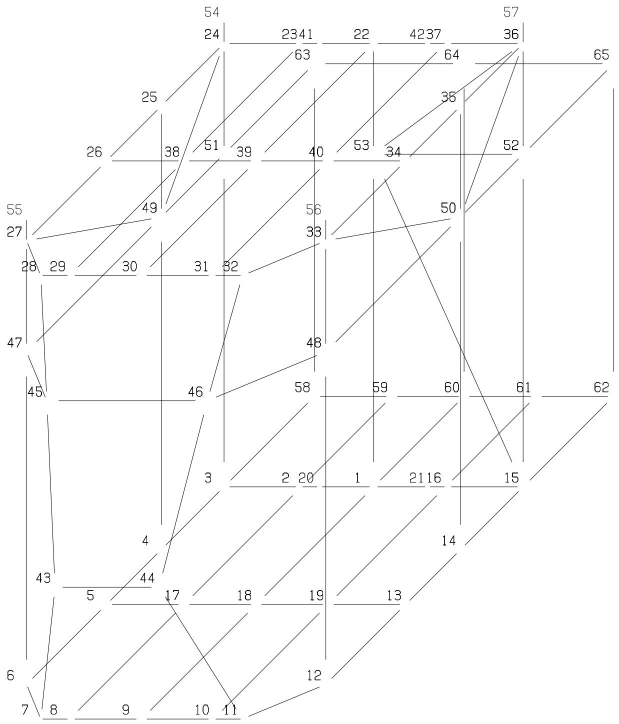
Geometry of the numerical model of the cabin structure prototype with the number of nodes and beam finite elements is shown in Figs. 2 and 3. The model has 65 nodes and 111 finite elements of the beam type.

Cabin prototype structure has the following characteristics: glass area of 8.2 m^2; steel structure mass of 470 kg; combined mass of the operator and chair of 150 kg.

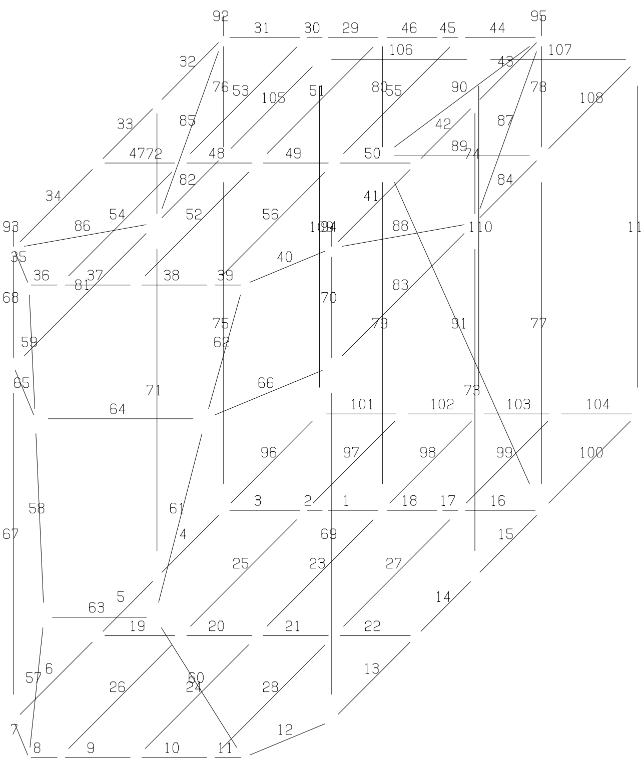
Shown in Figs. 4 and 5 are the models for static and dynamic calculation of the cabin prototype structure.

Static calculation

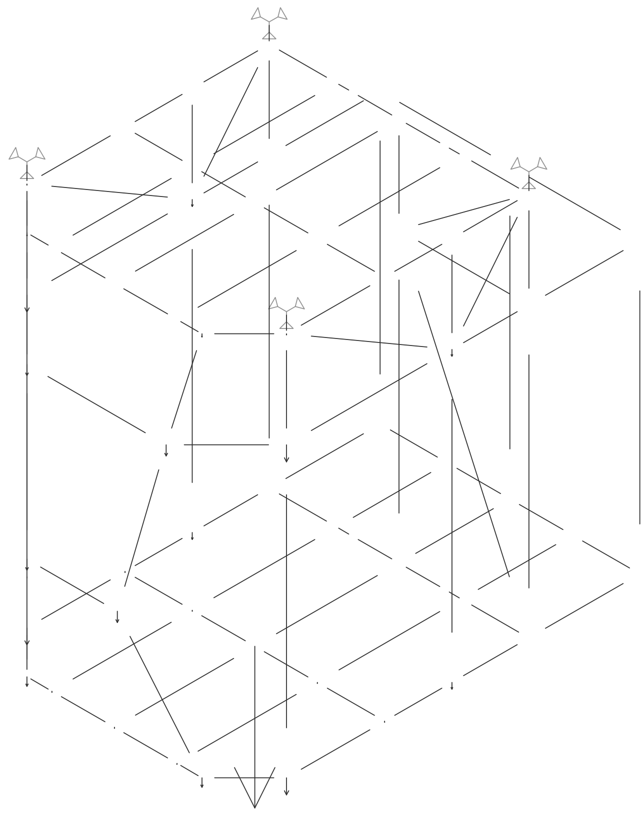
Results of static calculation are shown in Figs. 6-7. Results of static calculation of the cabin prototype structure have shown very small values of deformation (deflection) of all nodes within the model in all directions, along with very low stress values in all elements of the cabin prototype model, while simultaneously pointing out the fact that the stiffness of the cabin prototype structure is extremely high.



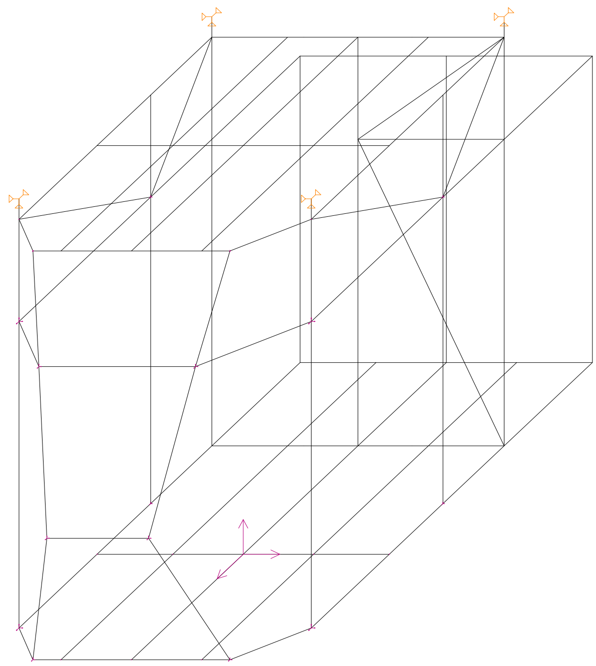
Slika 2. Geometrija proračunskog modela konstrukcije kabine sa brojevima čvornih tačaka
Figure 2. Cabin structure geometry of the model including node numbers.



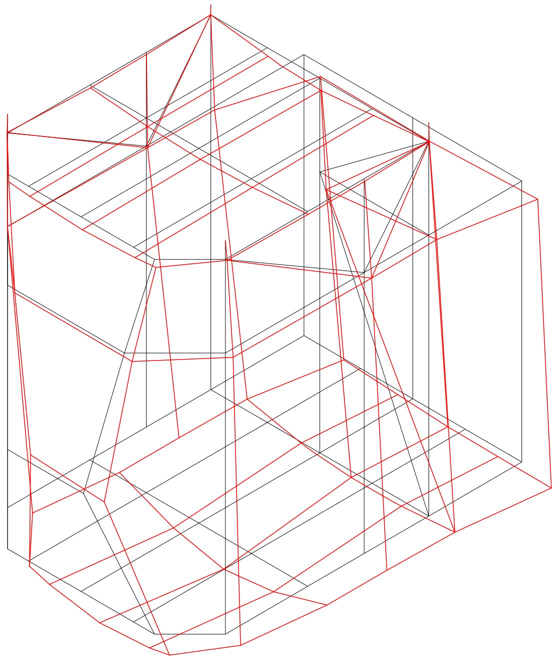
Slika 3. Geometrija proračunskog modela konstrukcije kabine sa brojevima konačnih elemenata tipa grede
Figure 3. Cabin structure geometry of the model including the numbers of beam type finite elements.



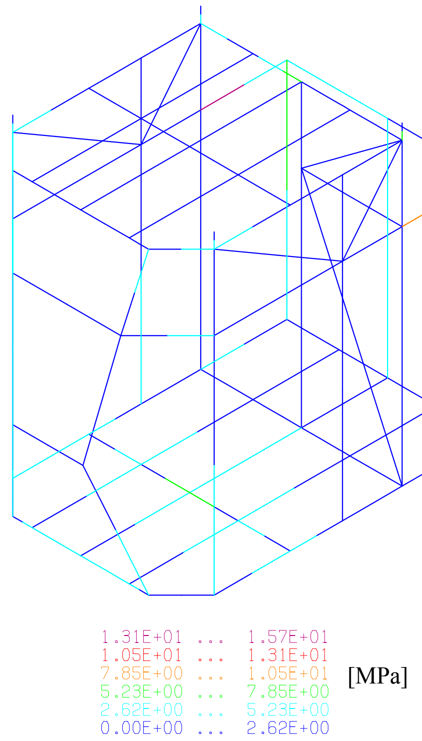
Slika 4. Model konstrukcije prototipa kabine za statički proračun
Figure 4. Cabin prototype model used for static calculation.



Slika 5. Model konstrukcije prototipa kabine za dinamički proračun
Figure 5. Cabin prototype model used for dynamic calculation.



Slika 6. Deformacija (ugibi) elemenata konstrukcije prototipa kabine - f_{max} = 0,12 mm (ugib maksimalno deformisane tačke modela prototipa kabine)
Figure 6. Deformation (deflection) of cabin prototype elements - f_{max} = 0.12 mm (deflection of a cabin prototype model node with highest deformation).



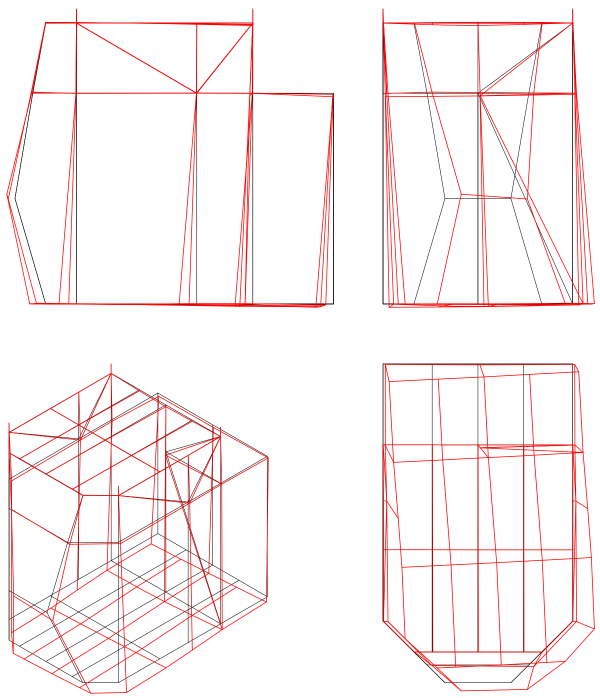
Slika 7. Naponsko stanje elemenata konstrukcije prototipa kabine
Figure 7. Stress state of cabin prototype structural elements.

Dinamički proračun

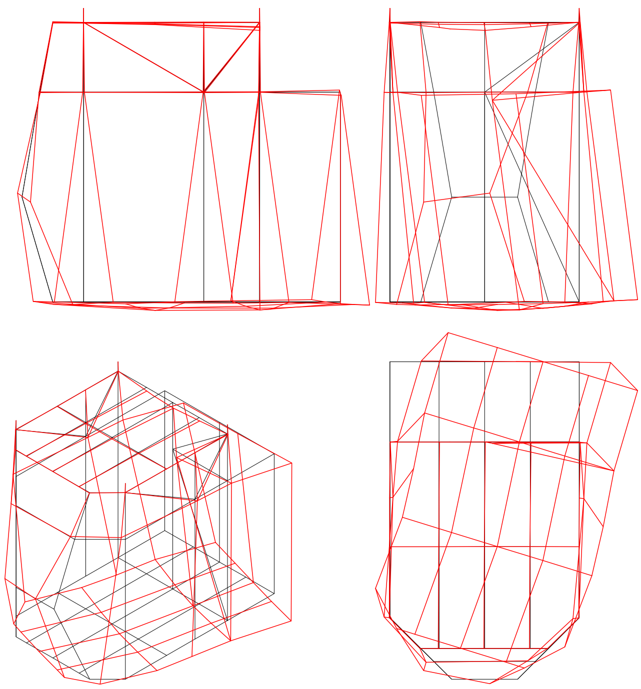
Dinamički proračun elemenata modela noseće konstrukcije prototipa kabine je obuhvatio sledeće, sl. 9-11:
- sopstvene frekvencije i glavne oblike oscilovanja (prvi i treći)
- prinudne prigušene oscilacije u frekventnom domenu.

Dynamic calculation

Dynamic calculation of support structure elements for the cabin prototype model include the following, Figs 9-11:
- eigen-frequencies and main oscillation modes (the first and third)
- forced damped oscillation within the frequency range.



Slika 9. Prvi glavni oblik oscilovanja - f_{o1} = 20,3 Hz
Figure 9. First mode of oscillation - f_{o1} = 20.3 Hz.



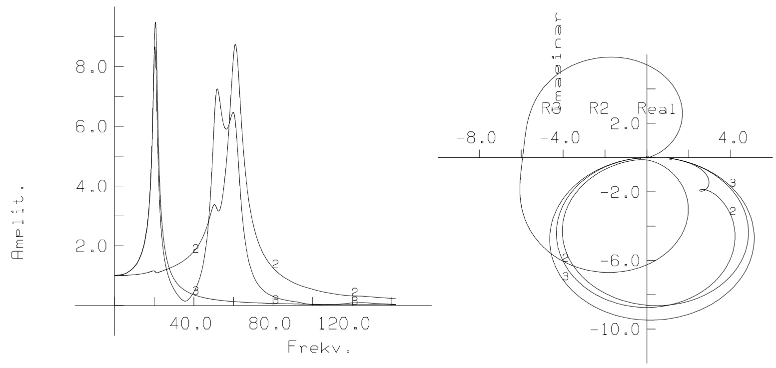
Slika 11. Treći glavni oblik oscilovanja - f_{o3} = 51,1 Hz
Figure 11. Third mode of oscillation - f_{o3} = 51.1 Hz.

Na sl. 12 prikazan je dinamički odziv konstrukcije kabine na mestu sedišta od vertikalne pobude konstrukcije krana u frekventnom domenu. Evidentno je da su sopstvene frekvencije oscilovanja izuzetno visoke i da je dinamički odziv konstrukcije kabine na eventualnu pobudu od krana veoma povoljan, što je izuzetno važno zbog osećaja sigurnosti koju u tom slučaju dobija operater krana.

Shodno navedenom prototip kranske kabine izgleda kao na sl. 13.

Figure 12 shows dynamic response of crane cabin structure at the seat location due to vertical excitation of the crane structure within the frequency domain. It is evident that eigen-frequencies of oscillations are extremely high and dynamic response of the cabin from eventual crane excitation is approving, being so important because of the sense of security the crane operator experiences in this case.

Based on aforementioned, the cabin prototype resembles that in Fig. 13.



Slika 12. Dinamički odziv konstrukcije kabine od vertikalne pobude konstrukcije krana
Figure 12. Dynamic response of the cabin due to vertical exciting of the crane structure.

Slika 13. Prototip kabine, bočno-čeoni pogled
Figure 13. Cabin prototype, lateral-front view.

ZAKLJUČAK

Većina današnjih kranskih kabina je projektovana na principima koji su postavljeni pedesetih godina prošlog veka, što jasno ukazuje na potrebu za razvojem nove generacije kabina. Uprkos tome što su uzrok ogromnog broja nesreća, današnje kabine kranova najčešće nisu projektovane u skladu sa antropo- merama operatera.

Krajnji cilj ovog rada je rešavanje problema koji se javljaju pri rukovanju kranovima sa postojećim konceptom kabina, i da praktično eliminiše ili smanji probleme operatera koji dovode do manjeg iskorišćenja kapaciteta krana i problema industrijske bezbednosti. Novorazvijena kranska kabina je održiv proizvod sa manje angažovanih resursa, zahvaljujući umanjenju mase i povećanju prilagodljivosti čoveku. Projektovana i dizajnirana konstrukcija kabine je u potpunosti zadovoljila postavljene zahteve. Pošto je statička i dinamička krutost konstrukcije kabine izuzetno povoljna i visoka, zaključujemo da je moguće izvesti zamenu izabranog materijala konstrukcije kabine (S325J2G3) sa legurom aluminijuma. U radu /10/ je analizirana ekonomska isplativost proizvodnje i upotrebe nove generacije kranske kabine sa rešenim problemom vidljivosti pomoću video kontrole, gde je dokazano je da su ukupne koristi korišćenja kabine u celokupnom periodu eksploatacije višestruko veći od nabavne cene kabine. Interna stopa prinosa kao relativna mera ekonomske isplativosti kupovine i eksploatacije nove generacije kranske kabine je nekoliko puta veća od relevantne ponderisane kamatne stope, a period povrata iznosi manje od tri godine, što podrazumeva visoku profitabilnost investicije i svrstava projekat u kategoriju projekata sa jako niskim rizikom.

CONCLUSIONS

Majority of today's crane cabins are designed on principles established during the 50's of the last century, clearly indicating the need for developing a new generation of cabins. Despite being the cause of a large number of accidents, modern crane cabins are typically not designed according to the anthropometrical measures of the operator.

The final goal of this paper is to solve the problems that occurred during operating of cranes with the existing cabin concept, and to practically eliminate or reduce the problems operators have, which lead to the reduced use of crane capacity, as well as industrial safety issues. Newly developed crane cabin represents a sustainable product with less engaged resources, thanks to the reduced mass and increased adaptability to human needs. The designed cabin construction entirely meets the required demands. Since both the static and the dynamic stiffness of the cabin is extremely favourable and high, it is concluded that it is possible to replace the selected material used for the cabin (S325J2G3) with an aluminium alloy. Analysed in /10/, the cost effectiveness of manufacturing and using the new generation of crane cabins with the solved problem of visibility, by using video controls, where it was proven that the total benefits of using the cabin throughout the entire exploitation period are several times greater than its purchasing price. The internal return rate, as a relative measure of cost effectiveness of the purchase and exploitation of the new generation of crane cabins is several times higher than the relevant pondered interest rate, whereas the return period is less than three years, which implies high profitability of the investment and places this project in a very low risk category.

Preporuka za dalja istraživanja bi bila da idu u pravcu proučavanja buke, vibracija, osvetljenja, temperature i vlažnosti vazduha u kabinama kranova. Kontrolni organi takođe ostavljaju dosta prostora za dalja istraživanja.

ZAHVALNICA

Ovaj rad je podržan od strane Ministarstva prosvete, nauke i tehnološkog razvoja Republike Srbije – projekti E!6761, TR35040 i TR 35017.

Recommendation for further research would be to continue the study of the effects of noise, vibrations, lighting, temperature and air humidity in crane cabins. Control authorities also leave a lot of space for further research.

ACKNOWLEDGEMENTS

This paper is supported by the Ministry of Education, Science and Technological Development of Republic of Serbia - projects E!6761, TR35040 and TR 35017.

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