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28th - 30th November 2012.

Jahorina, B&H, Republic of Srpska



University of East Sarajevo

Faculty of Mechanical Engineering

Conference on Mechanical Engineering Technologies and Applications

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PREFACE

Production in developed countries is based on the modernization and optimization of the production processes with the application of new technologies that are the result of scientific research. The application of new technology enables companies efficient production and competitiveness in the world market.

Faculty of Mechanical Engineering, University of East Sarajevo, organizes the First international conference "COMETa2012 - Conference on Mechanical Engineering Technologies and Application", which has tasks: to increase economic competitiveness in the region and the create a unique European Research Area.

Globally, the worldwide we are witnessing a rapid development and a host of new technological solutions, which occur primarily in the multidisciplinary development (mechatronics) but also in development of completely new technologies, such as nanotechnology, new energy sources, intelligent machines and processes, micro-technique, etc. All of this puts researchers and engineers in the new challenges and creates opportunities for products and technologies that provide a precondition for economic recovery and creation of new jobs.

COMETa2012 conference program structure is consisted of the following thematic areas: Production technologies and advanced materials, Applied mechanics and mechatronics, Development of products and mechanical systems, Energetics and thermo - technique, Renewable energy and environmental protection, Quality, management and organization, Maintenance and technical diagnostics.

Participation in international conference COMETa2012 was achieved by: 182 authors from 9 countries, with a total of 90 papers, including 4 plenary and 3 of introductory, 4 leading commercial companies and many small and medium enterprises. Bruel & Kjeaar Workshop: "Measurement of noise and vibration", was also organized at the conference, as well as a round table discussion: "The importance of quality infrastructure of B&H within the European integration".

The presence of a large number of participants from Bosnia and Herzegovina and abroad as well as the problems which are processed at the conference, coincide with the themes promoted by the European Union in its development programs.

On the basis of previous exposure, a gathering of scientists and researchers at the international conference COMETa should be understood not only as an exchange of knowledge and achievements of the narrower set of scientists and researchers, but also as a constant and serious attempt to focus social consciousness and social life on activities that ensures progress and prosperity of any society, and that is productive work, creating new knowledge and economic development.

On behalf of the Organizing Committee of the Conference COMETa2012, thank all authors, reviewers, as well as institutions, companies and individuals who contributed to realization of the Conference.

East Sarajevo, October 28th, 2012.

President of the Organizing Committee

Prof. dr Ranko Antunović



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PROGRAMSKI SISTEM ZA PRORAČUN MAŠINSKIH ELEMENATA - PROGRAMSKI MODUL ZA PRORAČUN FRIKCIONIH PRENOSNIKA

Dragan Milčić¹, Miroslav Mijajlović², Boban Anđelković³, Miodrag Milčić⁴

Rezime: Na Mašinskom fakultetu Univerziteta u Nišu već duže vreme se razvija programski sistema za proračun mašinskih elemenata i konstrukcija. U okviru programskog sistema PTD razvijeni su brojni programski moduli svrstani u tri celine: programski moduli za proračun elemenata za prenos snage, programski moduli za proračun elemenata za obrtno kretanje i programski moduli za proračun mašinskih spojeva. U radu je prezentiran aplikativni softver za proračun cilindričnih i konusnih frikcionih prenosnika. Za razvoj softvera korišćen je Visual Basic 6.

Ključne riječi: Programski sistem za proračun mašinskih elemenata, Frikcioni prenosnik

SOFTWARE SYSTEM FOR CALCULATIONS OF MACHINE PARTS – PROGRAM MODULE FOR FRICTION TRANSMISSION CALCULATIONS

Abstract: Faculty of mechanical engineering of University of Nis has been working for a long time period on development of the software system for calculations of machine parts and structures. Within software system PTD – Power Transmission Design many different program modules have been developed and they are grouped into three large groups: program modules for calculations of power transmission parts, program modules for calculations of rotation transmission and program modules for calculations of machine joints. Paper gives an overview on applicative software module for calculations of cylindrical and conical friction power transmissions. Software is developed within Visual Basic 6 environment.

Keywords: Software system for calculations of machine parts, Friction power transmission

1. UVOD

Tržište stalno postavlja sve složenije zahteve u pogledu produktivnosti, kvaliteta i brzine osvajanja novih proizvoda. Intenzivan tehnološki razvoj dovodi do porasta projektno - konstrukcijskih zadataka kao i do usložnjavanja sistema koji se

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razvijaju. Danas se u inženjerskoj praksi kao imperativ nameće primena računara u svim fazama procesa razvoja proizvoda.

Osnovni pravci primene računara u procesu razvoja proizvoda vezani su za zadatke:

- reprezentovanja i modeliranja,
- procesiranja i upravljanja podacima i informacijama,
- dokumentovanja,
- analiza i zaključivanja,
- proračuna i simulacija,
- pretraživanja,
- optimizacije,
- dijagnostike,
- procesiranja i upravljanja znanjem,
- sinteze, tj. generisanja koncepcije proizvoda.

Efekti primene računara u razvoju proizvoda su:

- kraće vreme ciklusa dizajniranja i smanjenje vremena do pojave proizvoda na tržište,
- smanjenje ukupnih troškova,
- poboljšanje kvaliteta,
- povećanje kompleksnosti proizvoda,
- povećanje broja dizajniranih varijanti,
- dislocirano konstruisanje, proizvodnja i održavanje.

Ovi efekti su mogući zahvaljujući: povećanju snage računara sa aspekta hardvera i komunikacija, povećanim sposobnostima softvera, povećanoj kompjuterskoj osposobljenosti dizajnera i inženjera, metodama koje omogućuju integrisanje CAx alata (Computer Aided X Tools), virtuelnom procesu razvoja proizvoda.

Iz svih ovih razloga, koji su napred navedeni, na Mašinskom fakultetu Univerziteta u Nišu se već duže vreme razvija programski sistem za proračun mašinskih elemenata i mašinskih konstrukcija - PTD.

2. PROGRAMSKI SISTEM ZA PRORAČUN MAŠINSKIH ELEMENATA

Ovaj programski sistem je, inače, deo inteligentnog integrisanog sistema za konstruisanje zupčastih prenosnika snage razvijenog na Mašinskom fakultetu u Nišu [1]-[3]. Programski sistem PTD je vrlo složene i heterogene strukture. Sistem je razvijen na modularnom principu koji omogućava izvršavanje, uz pomoć računara, pojedinih aktivnosti i zadataka konstruktora. Osnovni zadatak ovog sistema je da omogući integrisanu primenu različitih programskih modula i programskih sistema (CAD/CAE) razvijenih od strane autora i različitih softverskih kuća, a koji su namenjeni automatizaciji pojedinih aktivnosti u konstruisanju prenosnika snage. Zbog toga se softverska platforma razvijenog sistema, oslanja na maksimalnu primenu svih raspoloživih standarda u oblasti razmene podataka, komunikacija i računarstva.

Integrisani programski sistem PTD [4], [5] za proračun mašinskih elemenata, čija je arhitektura data na slici 1, čine tri celine:

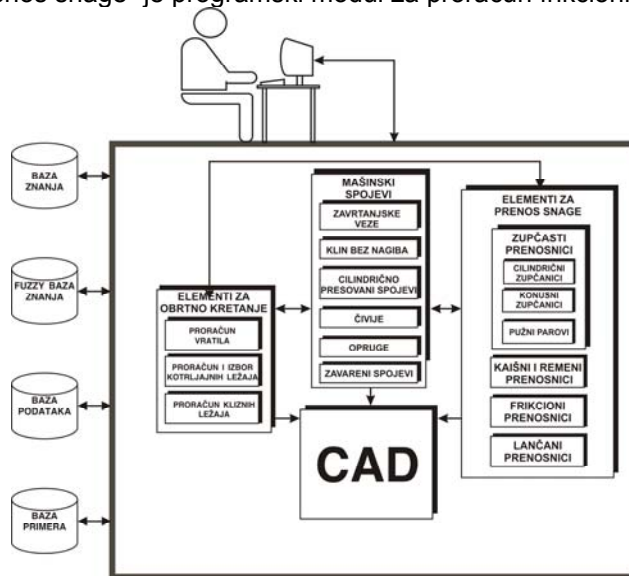
- programski moduli za proračun elemenata za prenos snage,
- programski moduli za proračun elemenata za obrtno kretanje,

- programski moduli za proračun mašinskih spojeva.

Prvom celinom programskog sistema PTD, koja se odnosi na proračun elemenata za prenos snage, obuhvaćeni su programski moduli za proračun cilindričnih, konusnih i pužnih zupčanika, frikcionih, lančanih, kaišnih i remenih prenosnika.

Drugom celinom obuhvaćeni su programski moduli za proračun vratila, proračun kliznih ležaja i proračun i izbor kotrljajnih ležaja, a trećom celinom obuhvaćeni su programski moduli za proračun klinova, žlebnih veza, cilindričnih presovanih spojeva, zavrtanjskih veza, opruga, čivija i zavarenih spojeva.

Nova verzija programskog modula u okviru programskog sistema PTD u delu „Elementi za prenos snage“ je programski modul za proračun frikcionih prenosnika.



Sl.1 Arhitektura programskog sistema PTD

3. PROGRAMSKI MODUL ZA PRORAČUN FRIKCIONIH PRENOSNIKA

Kod frikcionih prenosnika obrtni moment između pogonskog i gonjenog vratila prenosi se putem trenja i to njihovim neposrednim dodirivanjem. Da bi rad frikcionog prenosnika bio moguć potrebno je da sila trenja F_{μ} bude uvek veća ili, u graničnom slučaju, jednaka obimnoj sili F_t na frikcionim točkovima, odnosno $F_{\mu} \geq F_t$.

Potrebna sila trenja na dodirnim površinama frikcionih točkova dobija se pritiskom jednog frikcionog točka na drugi. Za prenos obimne sile F_t potrebna normalna sila između dodirnih površina iznosi:

$$F_n = \frac{F_t \cdot S_{\mu}}{\mu}, \quad (1)$$

gde je S_{μ} – stepen sigurnosti protiv klizanja, a μ – koeficijent trenja.

Na nosivost frikcionih prenosnika, pre svega, utiču: koeficijent trenja, dozvoljeni dodirni pritisak, otpornost u odnosu na habanje, odnosno radni vek i zagrevanje,

odnosno mogućnost odvođenja toplote. Nosivost frikcionog prenosnika zadovoljava ukoliko je radni površinski pritisak manji od dozvoljenog. Za linijski dodir Hercov površinski pritisak se određuje prema izrazu:

$$p = 0,418 \sqrt{\frac{K_A \cdot F_n \cdot E}{\rho_I \cdot b}} \leq p_{doz} \quad (2)$$

Za tačkasti dodir Hercov površinski pritisak iznosi:

$$p = 0,388 \sqrt{\frac{K_A \cdot F_n \cdot E^2}{(\rho_I / \gamma)^2}} \leq p_{doz} \quad (3)$$

Stribekov površinski pritisak za linijski dodir iznosi:

$$k = \frac{K_A \cdot F_n}{2\rho_I \cdot b} \leq k_{doz} \quad (4)$$

gde je K_A – faktor radnih uslova, F_n – normalna sila, E – ekvivalentni modul elastičnosti, ρ_I – ekvivalentni radijus krivine, b – efektivna širina po kojoj se frikciono tačkovi dodiruju, p_{doz} – dozvoljeni površinski pritisak, k_{doz} – dozvoljeni Stribekov pritisak, γ – faktor krivine.

The screenshot shows a software interface for calculating frictional transmission parameters. The window is titled "Frikcioni prenosnik". It contains several sections for input and output data:

- IZBOR TIPRA PRENOSNIKA:** A dropdown menu showing "cilindricni frikcioni prenosnik".
- IZBOR MATERIJALA I LEZAJA:**
 - Materijal točkova: "E360(haljeni čeli- podmazivanje mineralnim uljem)"
 - Tip lezaja: "za ugrađena 4 koštajna lezaja"
 - μ : 0.03
 - ε : 0.02
 - f : 0.05 mm
 - p_{doz} : 650 N/mm²
 - E : 205000 N/mm²
- ULAZNI PODACI:**
 - P_1 : 10 kW
 - n_1 : 1250 o/min
 - S_μ : 1.5
 - u : 2
 - ψ : 0.4
 - Karakter promene obrtnog momenta radne masine: "elektromotor-ravnomeran"
 - K_A : 1
- IZLAZNI PODACI (GEOMETRIJA FRIKCIONOG PRENOSNIKA):**
 - Racunske vrednosti:**
 - T_1 : 76.392 Nm
 - D_1 : 169.718 mm
 - D_2 : 339.437 mm
 - b : 57.8874 mm
 - i : 2
 - Usvojene vrednosti:**
 - D_1 : 180 mm
 - D_2 : 360 mm
 - b : 70 mm
 - a : 270 mm
- OSTALI IZLAZNI PODACI:**
 - F_{t1} : 848.8 N
 - F_n : 42440 N
 - F_{t2} : 848.8 N
 - n_2 : 625 o/min
 - T_2 : 152.784 Nm
 - V_1 : 11.7809 m/s
 - P_2 : 9.39724 kW
 - P_{GL} : 25 W
 - P_G : 802.759 W
 - η : 0.99972
 - η_F : 0.94222
 - ρ_1 : 90 mm
 - ρ_2 : 180 mm
 - ρ : 60 mm
 - P_{GF} : 577.759 W
 - p : 803.077 N/mm²

Sl.2 Unos neophodnih podataka za proračun frikcionih prenosnika

Frikcioni prenosnici se mogu podeliti u dve osnovne grupe: prenosnici sa konstantnim prenosnim odnosom i prenosnici sa (regulisanim) promenljivim prenosnim

odnosom ili varijatori. Svaka od napred navedenih grupa obuhvata veći broj prenosnika koji se međusobno razlikuju prema konstrukcionom izvođenju. Zavisno od položaja obrtanja vratila, frikcionni prenosnici mogu biti izvedeni kao cilindrični i konusni. Programskim modulom za proračun frikcionih prenosnika obuhvaćena su ova dva tipa konstrukcionih izvođenja frikcionih prenosnika.

Korisnik softvera opciono bira proračun cilindričnih ili konusnih frikcionih parova. U sledećem koraku se definiše materijal frikcionih točkova. Za izabrani materijal softver daje srednje vrednosti za koeficijent trenja μ , klizanje ε , krak trenja kotrljanja f , dozvoljeni površinski pritisak p_{doz} i ekvivalentni modul elastičnosti E . Naravno, korisnik softvera ove vrednosti može da promeni i unese neke druge.

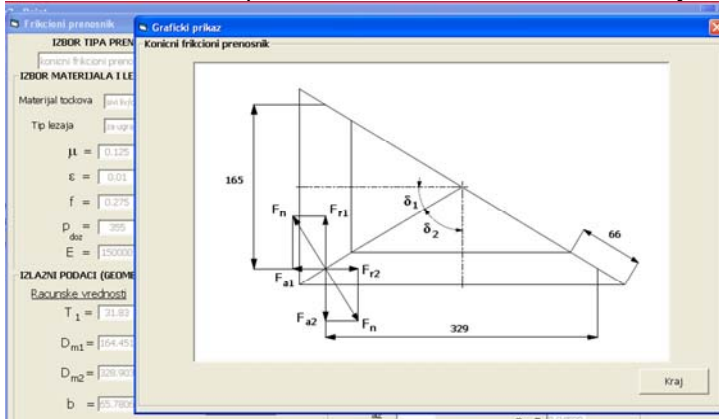
Sl.3 Rezultati prethodnog proračuna frikcionih točkova

Sl.4 Ostali rezultati proračuna

Da bi se izvršilo dimenzionisanje frikcionog prenosnika neophodno je uneti sledeće ulazne podatke: snagu na ulazu P_1 u kW, ulazni broj obrtaja n_1 u min^{-1} , Stepen sigurnosti protiv klizanja S_μ (u preporučenim granicama 1,4 do 2), prenosni odnos u , i odnos širine i prečnika ψ (za cilindrične frikционе točkove u granicama 0,2 do 0,8, a za konusne od 0,2 do 0,4). Faktor radnih uslova K_A se određuje na osnovu vrste pogonske mašine i karaktera promene obrtnog momenta radne mašine.

Na bazi unetih podataka i klikom na dugme PRORAČUN vrši se dimenzionisanje frikcionih točkova – određivanje prečnika D_1 , D_2 i širine b kod cilindričnih frikcionih točkova, odnosno prečnika u srednjem preseku D_{m1} , D_{m2} i širine b kod konusnih frikcionih točkova (sl. 3). Softver daje korisniku predlog usvojenih vrednosti prečnika, ali se pruža korisniku da usvoji vrednosti prečnika D_1 odnosno D_{m1} i zajedničke širine točkova b . Ostali podaci proračuna su dati na formi (sl. 4) odnosno mogu da se odštampaju u vidu Word dokumenta. Takođe korisnik softvera može u vidu

grafičkog prikaza da vidi frikcioni par sa sračunatim osnovnim dimenzijama (sl. 5).



Sl.5 Rezultati proračuna

4. ZAKLJUČAK

Na osnovu napred navedenog može se zaključiti sledeće:

- Na Mašinskom fakultetu Univerziteta u Nišu već duže vreme se razvija programski sistem PTD, koji je u početku bio namenjen za konstruisanje prenosnika snage, a danas prevazilazi prvobitnu ideju i obuhvata proračun gotovo svih mašinskih elemenata.
- Sastavni deo integrisanog programskog sistema za konstruisanje prenosnika snage-PTD, koji se razvija na Mašinskom fakultetu u Nišu, je programski modul za proračun frikcionih prenosnika, koji olakšava i ubrzava aktivnosti konstruisanja.

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