

Prilog primeni teorije obrade fotografija pri određivanju srednjeg specifičnog pritiska pneumatika na tlo kod motornih vozila

Miroslav Đemić^{1*}, Slavko Muždeka², Aleksandar Đurić²

¹Akademija inženjerskih nauka, Beograd (Srbija)

²Vojna akademija, Univerzitet odbrane u Beogradu, Beograd (Srbija)

Jedna od najvažnijih karakteristika specijalnih (vojnih) motornih vozila je mogućnost kretanja van uređenih saobraćajnica. Da bi se obezbedile odgovarajuće karakteristike prohodnosti, vojna vozila treba da, između ostalog, ispune zahteve u pogledu geometrijskih parametara prohodnosti, vučnih karakteristika, karakteristika stabilnosti, kao i mogućnosti savladavanja prepreka male nosivosti. Kako je kontakt pneumatika i tla veoma značajan za obezbeđivanje odgovarajućih performansi motornih vozila, njemu se mora posvetiti značajna pažnja. Imajući to u vidu, u ovom radu je razvijena i ilustrovana metoda izračunavanja specifičnog pritiska pneumatika i tla uz primenu teorije obrade fotografija.

Ključne reči: Vozilo, Pneumatik, Tlo, Otisak, Specifični pritisak

1. UVODNA RAZMATRANJA

Jedna od najvažnijih karakteristika specijalnih (vojnih) motornih vozila je mogućnost kretanja van uređenih saobraćajnica. Da bi se obezbedile odgovarajuće karakteristike prohodnosti, vojna vozila treba da, između ostalog, ispune zahteve u pogledu geometrijskih parametara prohodnosti, vučnih karakteristika, karakteristika stabilnosti, kao i mogućnosti savladavanja prepreka male nosivosti. Da bi se obezbedile što bolje performanse savladavanja prepreka male nosivosti neborbena terenska motorna vozila točkaši opremaju se specijalnim pneumaticima i sistemom za centralnu regulaciju pritiska vazduha [1]. Ovi sistemi pored obezbeđivanja manjeg specifičnog pritiska obezbeđuju i veću pouzdanost kretača, pošto omogućavaju nadoknadu gubitka vazduha koji može biti prouzrokovan probijanjem pneumatika.

Neborbena motorna vozila starije generacije bila su opremljena specijalnim dijagonalnim pneumaticima niskog pritiska sa unutrašnjom gumom koji su obezbeđivali vrlo niske specifične pritiske i odlične karakteristike prohodnosti po podlogama male nosivosti. Novije generacije vozila, međutim, imaju radijalne pneumatike nove generacije koji imaju daleko viši radni pritisak, što neminovno dovodi i do povećanja specifičnog pritiska na podlogu. Ipak, zahvaljujući pre svega konstrukciji pneumatika, povećanje specifičnog pritiska nije tako drastično. Kako je kontakt pneumatika i tla veoma značajan za obezbeđivanje odgovarajućih performansi motornih vozila, njemu se mora posvetiti značajna pažnja [2].

Imajući u vidu da je cilj ovog rada razvoj metode za određivanje specifičnog pritiska pneumatika i tla, ocenjeno je celishodnim da se, u najkraćim crtama, osvrnemo na rezultate nekih istraživanja. Problem kontakta pneumatika i tla na zemljanim putevima je detaljnije objašnjen u [3]. Rezultati eksperimentalnih istraživanja kamionskih pneumatika su pokazali da sa povećanjem pritiska vazduha u pneumaticima i povećanjem radijalnog opterećenja raste srednji specifični pritisak između pneumatika i tla. Knjiga [4] je kompletno posvećena teramehanici, posebno izračunavanju i merenju stvarnih opterećenja tla kod

raznih tipova vozila (vojnih, kamiona, putničkih vozila, traktora i sl.). Posebno je apostrofiran odnos pneumatika i deformabilnog tla. U [5] autori ukazuju na važnost istraživanja odnosa pneumatik-deformabilno tlo kod teretnih vozila. Razvijena je metoda merenja otiska pneumatika na deformabilnom tlu i razvijen program za analizu podataka. Autori u [6] daju prikaz konvencionalnih i nekonvencionalnih postupaka za merenje specifičnog pritiska pneumatika i tla. Posebno je opisana metoda zasnovana na akustičnim fenomenima. Problem modeliranja odnosa pneumatika i tla je posebno razmotren u [7], a interakcija pneumatika i tla sa aspekta uticaja različitih tipova putnog pokrivača na karakteristike motornih vozila je detaljno razmotrena [8].

Imajući u vidu prikaze dela publikovanih materijala iz ove oblasti, možemo zaključiti da je ovaj problem aktuelan, posebno kod teretnih motornih vozila koja su namenjena i za kretanje van puteva. Zbog toga je u ovom radu učinjen pokušaj da se razvije metoda za ocenu specifičnog pritiska pneumatika i tla zasnovana na teoriji obrade fotografija [9,10]. Ona je ilustrovana primerom primene kod motornog vozila proizvodnje FAP 1118 BS/AV [1], sa pneumaticima Continental 13 R 22.5, a njen opis će biti prikazan u narednom tekstu.

2. KORIŠĆENA METODA

Osnovni pokazatelj prohodnosti terenskih vozila po terenima male nosivosti je specifični pritisak na podlogu [2]. Ispitivanje je realizovano merenjem opterećenja prednjeg levog točka i površine otiska pneumatika na tvrdu podlogu. Masa koja se prenosi na pomenuti točak za neopterećeno vozilo je iznosila 2395 daN. Kod ovakvih vozila se pri opterećenom stanju težina na prednjem točku povećava za oko 10%, što i nije velika razlika, pa je odlučeno da se ispitivanja obave samo sa neopterećenim vozilom. Prilikom merenja variran je pritisak u pneumaticima u opsegu koji je proizvođač deklariseo za putne i terenske uslove vožnje [1].

Merenje opterećenja točka vršeno je pomoću osovinskih vaga tipa VOP, mernog opsega 0-14000±20 daN. Pritisak u pneumaticima je očitavan na manometrima sistema za centralnu regulaciju pritiska vazduha (CRPV),

*Kontakt adresa autora: Akademija inženjerskih nauka, Beograd, demic@kg.ac.rs

uz poštovanje uslova da se pritisak očitava neposredno nakon oslanjanja točka na vagu. Da bi se obezbedilo da ne dođe do većeg pada pritiska u sistemu zbog gubitaka vazduha na spojevima (prelazu na vratila pogonskih točkova) obezbeđeno je da motor radi sve do trenutka merenja, a da se u trenutku merenja isključi. Da bi se obezbedio adekvatan otisak pneumatici su premazivani crnom bojom. Izračunavanje površine otiska vršeno je na osnovu fotografije otiska sa papira o čemu će kasnije biti više reči.

3. OBRADA PODATAKA

Da bi se lakše utvrdila razmera fotografije i prava veličina otiska, isti je fotografisan uz postavljeni lenjir. Dimenzije fotografije (u pikselima i cm) određene su uz korišćenje programa PhotoPos Pro 3. Radi ilustracije, na Slici 1. prikazana je fotografija otiska prednjeg točka za pritisak vazduha od 7.5 bara.



Slika 1: Otisak pneumatika prednjeg točka pri pritisku od 7.5 bara i opterećenju od 2395 daN (dimenzija fotografije 14.1*12.29, cm -533*487 Piksela)

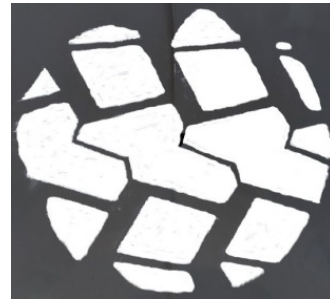
Imajući u vidu da je cilj ovog rada razvoj metode zasnovane na teoriji obrade fotografija, ocenjuje se celishodnim da se u narednom tekstu ukaže na elementarne pojmove o fotografiji.

U najkraćem, fotografija predstavlja matricu sa pikselima kao elementima [9]. Kod obrade fotografija se, najčešće, koristi osmобitni koncept, kod koga su amplitude svakog piksela definisane nivoima od 0 do 255 (crno bela fotografija). Obično se kao 0 uzima crna, a 255 bela boja, tako da u osmобitnom konceptu možemo imati 256 nijansi boja. Kod fotografije u boji (načesće se koristi model sa tri boje: crvena-zelena-plava, na engleskom RGB, i YCbCr - kombinacija boja koja se koristi kod TV prijemnika, videti [9]), pa tada 24-bitni pristup 8x8x8 = 256x256x256 daje približno 16 miliona kombinacija. U literaturi se, imajući u vidu način na osnovu kojeg se definišu amplitude – nivoi, obično podrazumeva da to predstavlja energiju boja. Kako je ova materija kompleksna i detaljno prikazana u [9], o njoj ovde neće biti više reči.

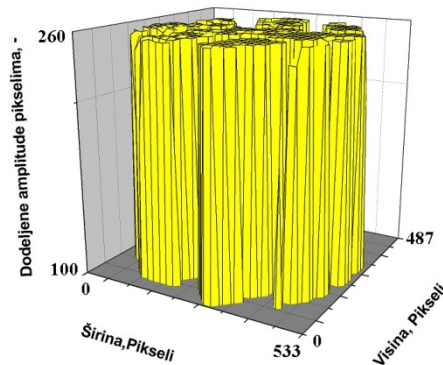
Za dalje analize je korišćen softver [10] koji je zasnovan na teoriji obrade fotografija i namenjen je izračunavanju 2D Furijeove transformacije. On posle učitavanja fotografije određuje njene dimenzije u pikselima i omogućava očitavanje matrice piksela fotografije. Na osnovu toga, posle izbora tipa skale (RGB, Gray Scale i sl.) izračunava realne, imaginarne ili moduo spektra 2D Furijeove transformacije. Rezultati mogu biti iskazani matricom izlaznih podataka ili rasterom. Takođe, omogućava i izračunavanje inverzne Furijeove transformacije.

Da bi se izračunala površina otiska, sve fotografije otisaka su digitalizovane primenom softvera [10]. Kako je isti definisan da bela boja bude prikazana vrednošću 255, a crna sa 0, ocenjeno je celishodnim da se uradi negativ svih fotografija otisaka, uz korišćenje softvera PhotoPos 3. Na taj način je bela boja prikazana crnom i obrtno, što je omogućilo da softver prepozna crnu boju sa vrednošću 255 (što je primerenije cilju naših istraživanja).

Radi ilustracije, na Slici 2. prikazujemo negativ fotografije sa Slike 1, a na slici 3, 3D digitalizovane fotografije sa Slike 2. (crnoj boji je data vrednost 255, a beloj 0).



Slika 2: Negativ fotografije sa Slike 1



Slika 3: 3D grafika fotografije sa Slike 2

Da bi se izračunala površina otiska, bilo je potrebno odrediti broj crnih piksela na originalnim fotografijama. U tom smislu je realizovan softver Povrsina Otiska Pneumatika (u Paskalu). Na osnovu broja crnih piksela, izračunato je relativno učešće crnih piksela na fotografiji, tj.:

$$rel = \frac{\text{broj crnih piksela}}{\text{broj piksela po dužini} \cdot \text{broj piksela po visini fotografije}} \quad (1)$$

Povrsina fotografije je izračunata na osnovu dimenzija koje su dobijene programom PhotoPos Pro 3.:

$$A = b \cdot h \quad (2)$$

gde je:

- b – širina, a
- h – visina fotografije u cm.

Kako je razmera otiska i fotografije određena uz pomoć postavljenog lenjira, stvarna površina otiska je data izrazom:

$$O = r_b \cdot r_h \cdot A \cdot rel \quad (3)$$

gde su r_b i r_h razmere za širinu i visinu fotografije.

Na osnovu izračunate površine otiska (O) i radijalnog opterećenja točka ($Z=2395$, daN) izračunat je srednji specifični pritisak na tlo, prema izrazu:

$$p = \frac{Z}{O} \quad (4)$$

Rezultati izračunavanja su prikazani u Tabeli 1.

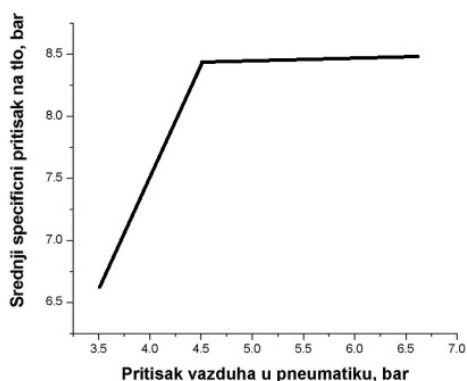
Tabela 1: Karakteristične veličine

Pritisak vazduha u pneumatiku (bar)	Relativno učešće crnih pikseli u fotografiji	Površina fotografije prekrivena crnim pikselima (cm ²)	Stvarna površina otiska, (cm ²)	Srednji specifični pritisak prednjeg točka neopterećenog vozila (bar)
3.5	0.496	125.35	362.27	6.61
4.5	0.474	99.50	283.52	8.44
5.5	0.463	94.40	282.54	8.47
6.6	0.517	87.27	252.21	9.49
7.5	0.520	94.52	212.76	11.25

4. ANALIZA PODATAKA

Podaci iz Tabele 1. pokazuju da relativno učešće crnih pikseli u površini fotografije prekrivenom crnim pikselima i stvarna površina otiska (površina fotografije pomnožena sa razmerom) zavise od pritiska vazduha u pneumatiku. Srednji specifični pritisak prednjeg točka posmatranog vozila na čvrsto tlo je izračunat na osnovu stvarnog opterećenja točka i stvarne površine otiska pneumatika i on je u ovom slučaju, uvek veći od pritiska vazduha u pneumatiku, a što je u saglasnosti sa podacima iz [3].

Radi ilustracije, srednji specifični pritisak na tlo u zavisnosti od pritiska vazduha u pneumatiku i radijalno opterećenje od 2395, daN prikazano je na Slici 4.



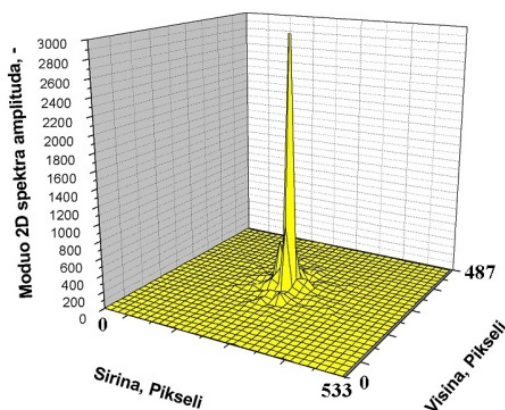
Slika 4: Specifični pritisak na tlo u zavisnosti od pritiska vazduha

Analizom podataka sa Slike 4. može se utvrditi da pritisak vazduha u pneumatiku utiče na specifični pritisak između pneumatika i tla. U konkretnom slučaju je veći specifični pritisak od pritiska vazduha u pneumatiku. Imajući u vidu da je tlo na kome su vršena merenja bilo čvrsto, očigledno je da konstrukcija pneumatika ima uticaja. U narednom periodu treba vršiti ispitivanja sa promenljivim radijalnim opterećenjem, kao što je to bio slučaj u [3], kada je u pitanju bila zemljana podloga.

Ocenjeno je celishodno da se istraži i promena srednjeg specifičnog pritiska po dužini i širini otiska. U te svrhe je celishodno izračunavanje modula spektara 2D Furijeove transformacije uz korišćenje pomenutog softvera i negativna fotografija otiska pneumatika.

Radi ilustracije, na Slici 5 prikazan je moduo spektara amplituda fotografije otiska pri 7.5 bara. Analiza svih spektara amplituda, čiji je ilustrativan primer prikazan

na Slici 5, je pokazala da se maksimalna vrednost pojavljuje na sredini fotografije (tako je softverski definisano) i da zavisi od pritiska vazduha u pneumatiku.



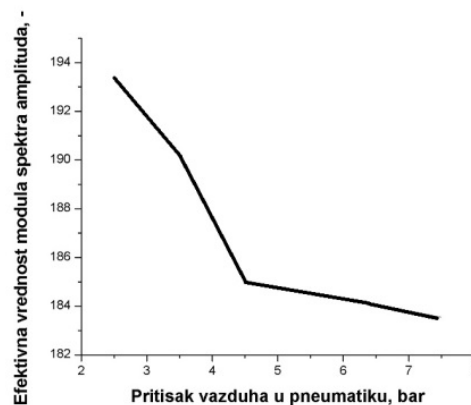
Slika 5: Moduo spektara amplituda za fotografije sa slika 2 i 3

Imajući u vidu da se pojavljuju i amplitude koje su manje od maksimalnih, ocenjeno je celishodno da se izračuna efektivna vrednost spektara za celu površinu fotografije. To je učinjeno uz korišćenje razvijenog programa u Paskalu RMSMatrica, a rezultati prikazani u Tabeli 2.

Tabela 2: Efektivne vrednosti modula 2D spektara amplitude

Pritisak (bar)	Efektivna vrednost
2.5	193.44
3.5	190.23
4.5	185.06
6.6	184.03
7.5	183.55

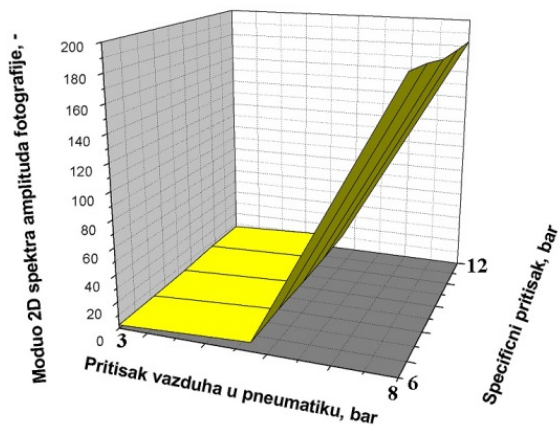
Podaci iz tabele 2 prikazani su i u grafičkom obliku na slici 6.



Slika 6: Zavisnost efektivne vrednosti modula 2D spektara amplituda od pritiska vazduha u pneumatiku

Analizom podataka iz Tabele 2. i slike 6. može se utvrditi da efektivna vrednost modula 2D spektara opada sa porastom pritiska vazduha. Najnižem specifičnom pritisku vazduha u pneumatiku odgovara najveća efektivna vrednost modula spektara amplituda fotografije. To, praktično, pokazuje da postoji relacija između tih veličina i da se i moduo amplituda može koristiti kao parametar za ocenjivanje specifičnog pritiska na tlo.

Ova činjenica će biti ilustrovana i 3D Slikom 7. na kojoj je prikazana zavisnost modula spektra amplituda od specifičnog pritiska i pritiska vazduha u pneumatiku.



Slika 7: Zavisnost modula spektra amplituda od specifičnog pritiska i pritiska vazduha u pneumatiku

Na osnovu prethodnih analiza, može se tvrditi da razvijena metoda daje pouzdane podatke i da se, u narednom periodu, može koristiti pri sličnim istraživanjima.

5. ZAKLJUČAK

Na osnovu izvršenih istraživanja može se zaključiti da razvijena metoda određivanja specifičnog pritiska između pneumatika i tla zasnovana na primeni teorije obrade fotografija može uspešno biti korišćena za definisanje odnosa pneumatika i tla.

Realizovana ispitivanja su pokazala da je specifični pritisak pneumatika 13 R 22.5 na tvrdoj podlozi uvek veći od pritiska vazduha u pneumatiku. U narednom periodu treba vršiti detaljnija ispitivanja sa različitim radijalnim opterećenjima pneumatika.

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Contribution to the Application of the Image Processing Theory in Determining the Middle Specific Tire Pressure on Ground at Motor Vehicles

Miroslav Demić^{1*}, Slavko Muždeka², Aleksandar Đurić²

¹Academy of Engineering Science, Belgrade (Serbia)

²Military Academy/University of Defence, Belgrade (Serbia)

One of the most important characteristics of the special (military) vehicles is possibility to move off-road. In order to achieve appropriate possibility characteristics, military vehicles need, beside other things, to fulfil geometric parameters of vehicle, traction characteristics, stability and ability to overcome obstacles of low load-bearing capacity.

The contact between tire and ground is very significant for ensuring adequate performance of motor vehicles and great attention must be paid to it. With that in mind, this paper has developed and illustrated the method for calculating specific tire pressure on ground with use of image processing theory.

Keywords: Vehicle, Tire, Ground, Tire print, Specific pressure

1. INTRODUCTION

One of the most important features of special (military) motor vehicles is possibility to move off-roads. In order to provide appropriate characteristics of pass ability, military vehicles, above others, need to fulfil geometric parameters of vehicle pass ability, traction characteristics, stability and ability to overcome obstacles of low load-bearing capacity. Modern military off-road motor vehicles use system for central pressure regulation and special off-road tires to fulfil the specific requirements for ability to overcome obstacles of low-bearing capacity [1]. These systems provide not just lower specific pressure but also higher reliability of tires, because they enable compensation for air loss caused by tire puncture.

Non-combat vehicles of the older generation were equipped with special diagonal tires with low pressures and tubeless that provided low specific pressures and good pass ability characteristics at obstacles of low-bearing capacity. New generations of vehicles, however, have new generation radial tires with higher pressures, which necessarily increase special pressure to ground. Increase of specific pressure is not those drastic, thanks to tire construction in first place.

The contact between tire and ground is very important in providing appropriate vehicle characteristics and it demand significant attention [2].

Taking into account that the goal of this paper is developing method for determining specific pressure of tire to ground, we will present some of the researches in this area that are being made in the past.

The problem of contact between tire soil roads is in more detail discussed in [3]. The experimental results of truck tires have show that increase of air pressure in tires and radial load is increasing medium specific pressure between tires and ground.

The [4] is entire dedicate to Tera mechanic, especially in determine and measurement of real road load at various vehicle types (military vehicles, trucks, tractors etc.). It is especially emphasized the relation between tire and deformable soil.

In [5] the authors point out the importance of research the tire-deformable soil relationship at trucks. The tire print method for deformable soil has been developed with program for data analysis.

The authors in [6] are showing conventional and non-conventional specific pressure measurement methods. It specifically describes method based on acoustic phenomena.

The problem of relations between tire and road is considered in [7], and interaction of tire and road with aspect of different types of travel cover influence at motor vehicle characteristics is more detail is worked out in [8].

Taking into account all shown in published materials in this area, we can conclude that problem is current, especially at trucks and various types of off-road vehicles. Because of that, this paper is giving one different approach in developing method for specific pressure of tires and ground assessment, based in image processing theory [9, 10]. It is illustrated in example with use motor vehicle FAP 1118 BS/AV [1], with Continental 13 R 22.5 tires, which will be more detail described in following.

2. USED METHOD

The main indicator of pass ability at off-road vehicles at low-bearing capacity ground is specific pressure [2]. For the purpose of method development, we have been measuring load at front left tire and tire print surface on hard surface. The mass transmitted at that tire for unlade vehicle was 2395 daN. With these types of vehicles, the loading of vehicle increases front tire mass for about 10%, which is not significant for this measurement, so it has been decided that all measurement

will be with unlade vehicle. The pressure in tires is varied during measurement in range which the manufacturer has declared for road and off-road driving conditions [1].

The load measurement has been done using VOP type axle scales, with measurement range 0–14000±20 daN. The pressure in tires was read at manometers of central regulation tires pressure system (CRPV), with compliance with the conditions that pressure is being read immediately after leaning the wheel on the scales. In preventing pressure drop in system at the joints (transition to drive wheel shafts) it is provided that engine is working until it is time for measurement and at the moment of the measurement is being turned off. The tire has been coated with black paint in order to provide adequate tire print. The calculation of tire print surface was done based on image, which will be more described in following.

3. MEASUREMENT AND DATA PROCESSING

For easier determination of the image drawing scale and real size of tire print, the wheel has been photographed with ruler being set. The image dimensions (in pixels and cm) have been determined using PhotoPos Pro 3 software. For illustration, Fig. 1 is showing image of front left tire print for air pressure of 7.5 bar.

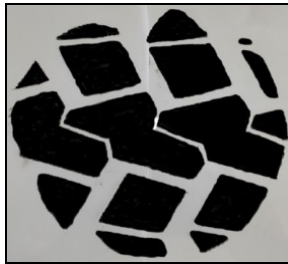


Figure 1: Front left tire print for pressure of 7,5 bar and load of 2395 daN (dimensions of image 14.1*12.29 cm, 533*487 Pixels)

Taking into account that the goal of this paper is developing the method based on, it will be image processing theory, in following it will be giving the basis knowledge and terms that are related with photography.

In short, the photography represent matrix in pixels as elements [9]. In image processing, we usually use eight-bit concept, which has all pixel amplitudes defined from level 0 to 255 (black and white image). Usually the 0 is taken as black and 255 as white colour, so that we can have in eight-bit concept 256 colour shade. With image in colour most usually we use model with three colours: red-green-blue or RGB and YCbCr-colour combination used at TV (see in [9]), and then 24-bit approach 8x8x8=256x256x256 is giving close by 16 million combinations. In different literature, bearing in mind the manner that defines amplitudes-levels, usually implies that it represents colour energy. The material that describes this is given more detail in [9] and it will not be more described in this paper.

For further analysis, is being used software [10] based on image processing theory which is developed for purpose and which is intended to calculate the 2D Fourier transform. After loading the image, software is determining its dimensions in pixels and allows reading image pixel matrix. Based on that, after selecting the scale

type (RGB, Gray Scale est.) it calculates real, imaginary, or magnitude of the 2D Fourier transform spectrum. The results can be shown in matrix of exit data or raster. Also, it allows and calculates inverse Fourier transform.

In order to calculate imprint surface, all images of tire print are being digitized using software [10]. Because the software defines that white colour is shown with value of 255 and black colour with value 0, we have been made negative of all images using PhotoPos 3 software. That way the white colour is shown as black and vice versa, which allows software to recognize black colour with value of 255 (which is more appropriately contain tests goal).

For illustration, picture 2 is showing negative of picture 1 and in picture 3, 3D digitized image from picture 2 (black colour is given value 255 and white 0).

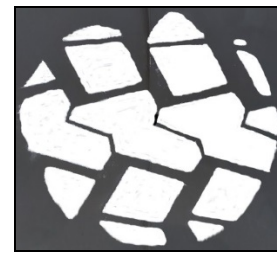


Figure 2: Image 1 negative

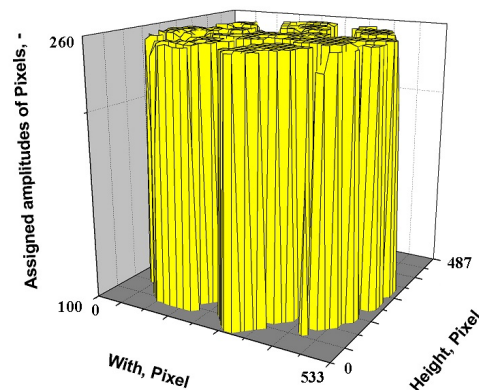


Figure 3: 3D graph from picture 2

In order to calculate the surface of tire print, it was significant to determine number of black pixels in original images. In that sense it has been realized software SurfaceTirePrint (in Pascal). Based on black pixel number, we calculated relative participation of black pixels on image:

$$rel = \frac{BlackPixelNumber}{WidthPixelNumber \cdot HeightPixelNumber} \quad (1)$$

The image surface was calculated based on dimensions given by PhotoPos Pro 3 software.:

$$A = b \cdot h \quad (2)$$

where is:

- b-width,
- h-height of the image in cm.

Proportion of the tire print and image is determined with help of ruler; the real surface of the tire print is determined with:

$$O = r_b \cdot r_h \cdot A \cdot rel \tag{3}$$

where r_b and r_h are proportions for width and height of image.

Based on the calculated tire print surface (O) and radial load of the wheel (Z=2395 daN) the middle specific pressure on ground is being calculated like:

$$p = \frac{Z}{O} \tag{4}$$

The calculated results are presented in Table 1.

Table 1: Calculated results

Air pressure in tire, bar	Relative participation of black pixels in image	Surface of image cover with black pixels	Real tire print surface cm ²	Medium specific pressure of front wheel unloaded vehicle, bar
3,5	0.496	125.35	362.27	6.61
4,5	0.474	99.50	283.52	8.44
5.5	0.463	94.40	282.54	8.47
6,6	0.517	87.27	252.21	9.49
7,5	0.520	94.52	212.76	11.25

4. DATA ANALYZE

The data from table 1 are showing relative participation of black pixels in image surface covered with black pixels and real tire print surface (surface of the image multiplied with proportion) depend on air pressure in tire. Middle specific pressure of the front wheel of the vehicle on hard ground is calculated based on real tire load and real tire print surface. In this case he is always bigger than air pressure in tire, which is in agreement with data in [3]. For illustration, medium specific pressure on ground related with tire air pressure and radial load of 2395 daN are shown in Fig. 4.

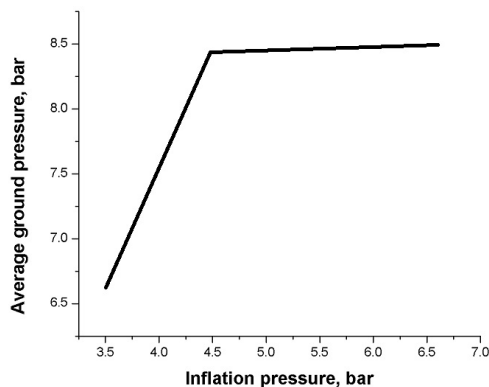


Figure 4: Specific pressure on ground related with tire air pressure

Analysing the data on picture 4, we can determine that tire air pressure is influencing at specific pressure

between ground and tire. Bearing in mind that ground was hard road, it is obvious that tire construction has influence. In future research we should have our focus on variable radial load, as it was done in [3], where the soil was dirt road.

It is considered expedient to research of medium specific pressure shift in length and width of tire print. For that purpose, it is expedient to calculate the magnitude of 2D Fourier transform using software and negative of tire print image.

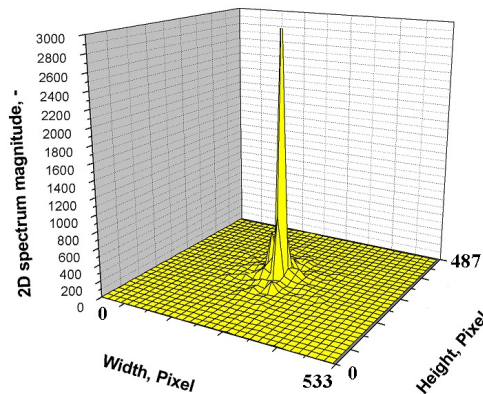


Figure 5: Magnitude of spectrum from pictures 2 and 3

For illustration, Fig. 5 is showing the magnitude of the spectrum of the tire print for 7,5 bar tire air pressure. The data analyze of all spectrums, which have been illustrated at Fig. 5, has shown that maximum values are at middle of the image (software id set like that) and that it depends on tire air pressure. Bearing in mind that we have also amplitudes lower than maximum value, it is assessed as expedient to calculate RMS value of the spectrum for whole image surface. It is done using developed software in Pascal RMS Matrix and results are shown in table 2.

Table 2: RMS of magnitude 2D spectrum

Pressure, bar	RMS
3,5	193.44
4,5	190.23
5.5	185.06
6,6	184.03
7,5	183.55

The data from table 2 are shown at Fig. 6 in graphic form.

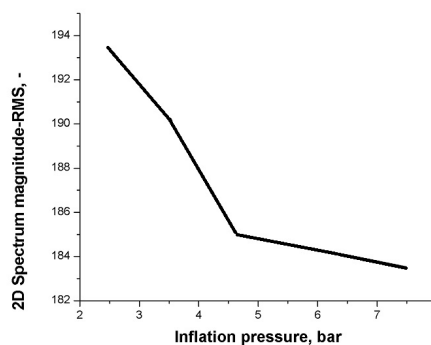


Figure 6: Dependance of RMS of the 2D magnitude spectrum from tire air pressure

Analysing the data from table 2 and Fig. 6 it can be determined that effective value of the magnitude of 2D spectrum is dropping with increase of the air pressure. The lowest specific tire air pressure is match with highest RMS value magnitude of the image spectrum. Practically, that shows that there is a relation between that values and that magnitude can be used as parameter for evaluation of the specific pressure on ground.

This will be illustrated with 3D graph at the Fig. 7 that shows dependence of the spectrum magnitude from specific pressure and tire air pressure.

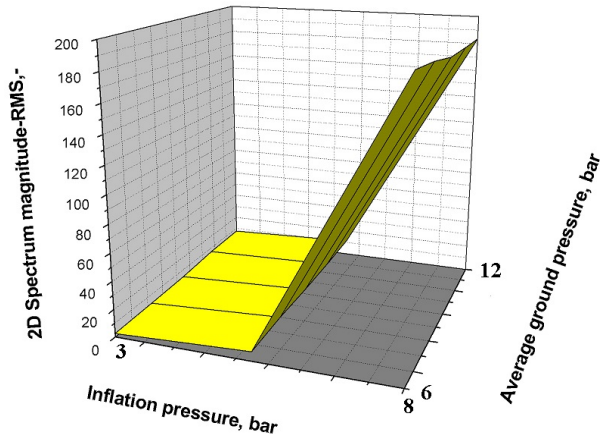


Figure 7: Dependence of the spectrum magnitude of the specific pressure and tire air pressure

Based on previous analyzes it can be it can be argued that method that has been developed is giving reliable data and can be used in, in future time for similar researches.

5. CONCLUSION

Based on the measurements that have been done and research, it can be conclude that developed method of deterring specific pressure between tire and ground based on the image processing theory can be successfully used for defining the relations between tire and ground.

Research that has been realized has shown that 13 R 22.5 tire specific pressure on hard ground is always bigger than tire air pressure.

In future time research must be done with different tire radial load.

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