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# EXAMINATION OF SENSITIVITY OF TRACTOR TIRE FILTERING BEHAVIOR TO CONTACT LENGTH CHANGE

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RESEARCH ARTICLE

**ABSTRACT:** Vibrations of agricultural tractors and other off-road vehicles are mainly excited through uneven ground encountered by such vehicles. Thereby tire acts as geometrical filter that transforms short-wavelength road undulations into effective excitation profile of milder geometry. Being geometrically conditioned, this filtering behaviour depends on tyre radial deflection i.e. contacts length. In this paper examination of sensitivity of filtering behaviour to contact length change is described and results are presented.

**KEY WORDS**: tractor tire, vibration, effective road profile



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## ISPITIVANJE OSETLJIVOSTI FILTRIRAJUĆEG PONAŠANJA TRAKTORSKOG PNEUMATIKA NA PROMENU DUŽINE KONTAKTA

**REZIME**: Vibracije poljoprivrednih traktora i drugih terenskih vozila uglavnom su izazvane neravninama terena po kojima se kreću ova vozila. Zbog toga se pneumatik ponaša kao geometrijski filter koji transformiše neravnine podloge kratkih talasnih dužina u efektivan profil pobude blaže geometrije. Budući da je geometrijski uslovljeno, ovo filtrirajuće ponašanje zavisi od radijalne deformacije pneumatika tj. dužine kontakta. U ovom radu je ispitivana je osetljivost filtrirajućeg ponašanja pneumatika na promenu dužine kontakta i dobijeni rezultati su prikazani.

**KLJUČNE REČI**: traktorski pneumatik, vibracije, efektivan profil puta

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## 1. INTRODUCTION

If tyre rolls over uneven ground whose irregularities have wavelength of the order of magnitude similar to tyre contact length, wheel centre will not follow exact ground geometry (as would be the case when using point-contact rigid follower instead of elastic tyre), but will travel along the path of different shape. If tyre motion happens in quasistatic manner, than tyre response (in view of the wheel centre trajectory shape) will have greater length and lower height compared to single road irregularity causing this response. This is the result of both tyre geometry and elasticity, and can be described as geometric low-pass filtering of the original road profile. Wheel centre trajectory is thereby considered effective road profile, since this motion represents real vehicle vibration excitation. This mechanism is depicted in Figure 1. This aspect of the tyre behaviour is referred to as „enveloping behaviour", since the tyre virtually envelopes i.e. wraps around ground irregularity of the short wavelength. Choosing quasistatic mode, it is possible to focus analysis purely on tyre enveloping behaviour, not taking into account tyre internal dynamics and vibration properties.

By using different combinations of tyre load and pressure, it is possible to obtain the same value of the length of contact area of the tyre with even ground. Furthermore, unambiguous relationship exists between contact length and radial tyre deflection [3, 4]. If values of these parameters change, the way of establishing contact between tyre footprint and road irregularities encountered by the tyre during motion also alters. This further leads to alteration of tyre enveloping behaviour i.e. geometric filtering properties. This phenomenon leads to conclusion that tyre contact length can be used as parameter of the tyre enveloping model. Such approach has already been used previously, e.g. [6, 7], though for road vehicle tyres.

Tractor tyre is characterized by significant differences in some aspects of its behaviour when compared to road tyres, above all due to different tyre structure and different relation between this physical structure and pneumatic contribution to tyre behaviour. In [1], results of examination have been published that shown that, although not completely accurate, approach of using tyre contact length as unique parameter of enveloping behaviour can be used as satisfying approximation, providing that tyre operational parameters are within usual range. Attaining higher level of model simplification additionally justifies adoption of this approximation. Primary topic of this paper is to obtain numerical quantification and qualitative assessment of the level and nature of contact length impact on tyre enveloping behaviour.

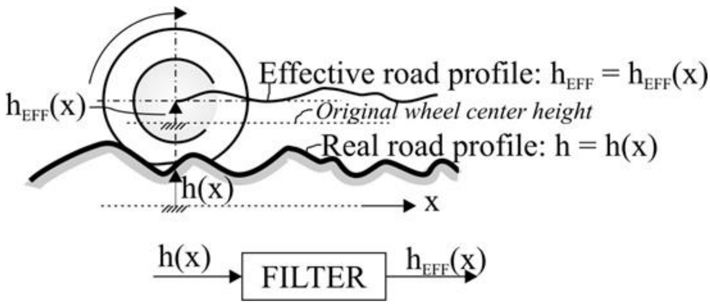


**Figure 1**. Concept of effective road profile: h(x) - ground profile shape, hEFF(x) - wheel centre trajectory based on h(x) and transformed by tyre filtering mechanism, x - direction of motion

## 2. EXPERIMENTAL SETUP AND METHOD

Tyre enveloping behaviour has been studied by measuring horizontal and vertical displacement of the wheel rolling very slowly over the singular road obstacle, in nearly quasistatic conditions (i.e. such that all kinds of dynamic excitation of the tyre structure can be considered negligible). Experimental facility used in these investigations is shown schematically in the Figure 2. It was described in more details in [2] and [5].

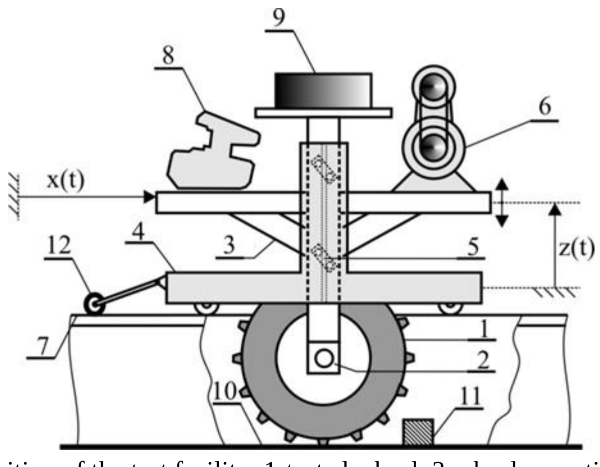


**Figure 2.** Composition of the test facility: 1-tested wheel, 3-wheel mounting frame, 4-wheel guiding cart, 11-road irregularity

Experimental measurements were made with the tyre of the size 12.4R28. Shape and dimensions of the road obstacle used for investigations are shown in the Figure 3.

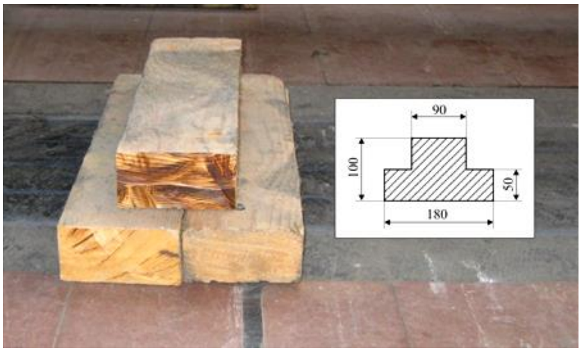


**Figure 3**. Shape and dimensions of the road obstacle used for investigations

Different levels of contact length were obtained by using constant tyre load of 960 daN and by varying tyre pressure. Four levels of contact length were used: 30, 35, 40 and 45 cm. Significant level of result fluctuations was observed, so in order to compensate for this, every measurement was carried out 10 times. Results were averaged and smoothed subsequently, so as to obtain representative response curves for each case.

Contact length was determined by measuring the distance between two tin plates placed along both front end rear edges of the tyre contact area, Figure 4. This method was described in more details in [3].

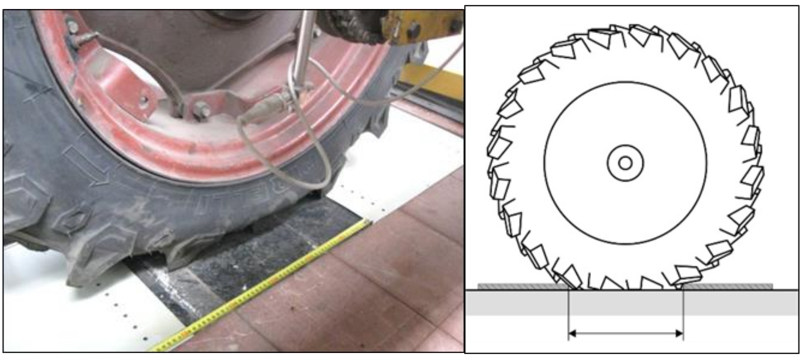

**Figure 4.** Measuring tyre contact length

## 3. RESULTS AND DISCUSSION

In order to quantify impact of contact length change on tyre filtering i.e. enveloping properties, measurements of tyre response curves have been made for different values of contact length. Geometric and spectral properties of response curves in different conditions were compared to each other.

In Figure 5, measurement results i.e. enveloping curves obtained are directly compared to each other. Vertical shift between the curves originates from the different levels of tyre centre due to different values of tyre deflection, at the same time enabling better visual overview of this comparison. Two main properties that can be clearly seen from the Figure 5 are:

1. Completely different shapes of individual curves
2. Significant difference in maximum values of response amplitudes.

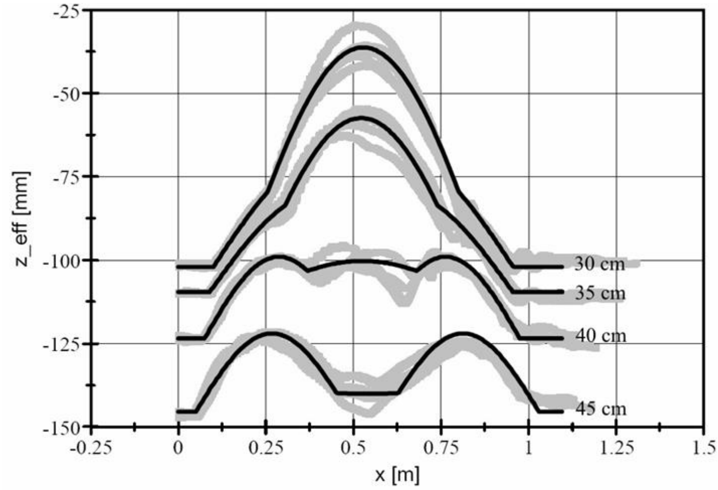


**Figure 5.** Enveloping curves obtained for different values of the contact length (values next to curves

In the Figure 6, zoomed area from the Figure 5 close to the origin is shown. In this figure it can be noticed that for greater value of contact length (corresponding to smaller level of radial deflection of the tyre) response curves start earlier, due to earlier contact with the obstacle. This also leads to the difference of the overall response curve length.

Conclusion that can be made on the basis of these results, corresponding to intuitive comprehension of tyre behavior, is that the effect of tyre low-pass filtering will be more pronounced for larger contact length. Therefore under such conditions amplitude response tends to decrease, while response length grows.

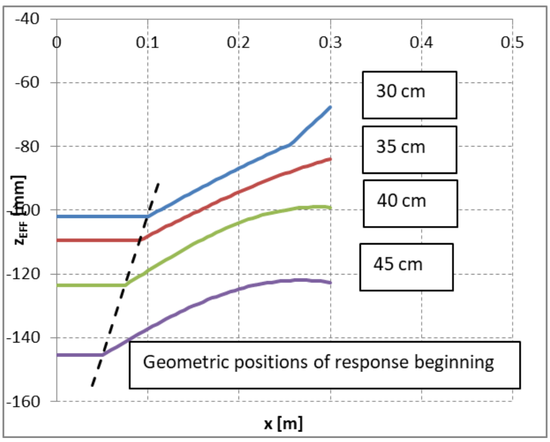


**Figure 6.** View of response curve beginning point (i.e. therefore overall length) change with the change of the contact length

Another view of investigation results is shown in Figure 7. In this view all response curves are shifted to the same referent ground level. For better visibility, only parts of curves left to the vertical symmetry axis are shown. This view shows properties noticed according to the previous figures, regarding main differences in tyre response for different contact lengths, more clearly.

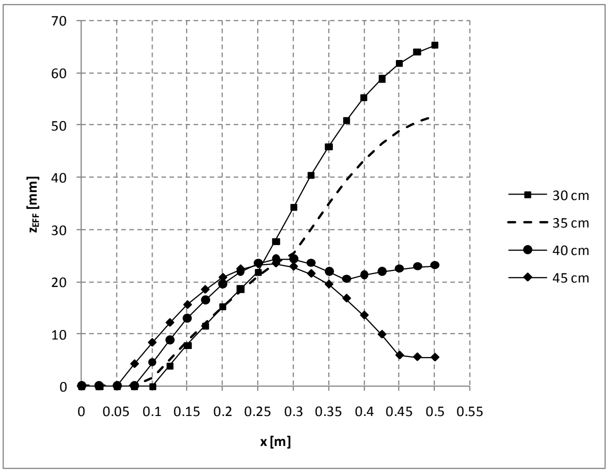


**Figure 7.** Response curves shifted to the same referent ground level

Finally, analysis of response curves spectral content is carried out in term of power spectral density. PSD curve of ground profile excitation is also shown for comparison. Results are shown in Figure 8. Change of response frequency content, which is indicator of filtering properties alteration, can be notified from the figure. Curves show that with increasing contact length, spectral content of the response curves decreases. It can also be seen that this change in tyre filtering behaviour is especially abrupt in transition of contact length values between 35 and 40 cm.

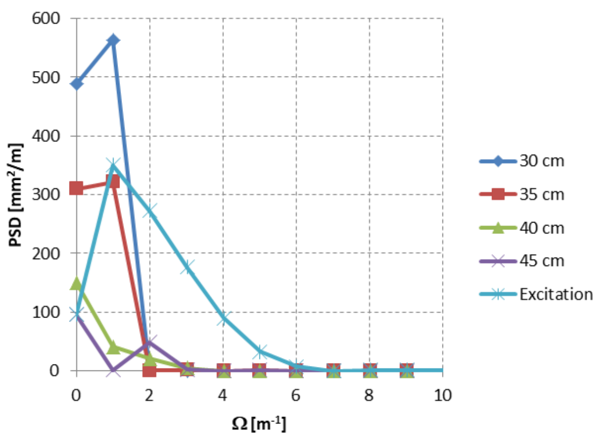


**Figure 8.** Spectral content of response curves and excitation

## 4. CONCLUSIONS

In order to quantify impact of contact length change on tyre filtering i.e. enveloping properties, measurements of tyre response curves have been made for different values of contact length. Geometric and spectral properties of response curves in different conditions were compared to each other.

Results of investigation have shown clearly that contact length change lead to significant variation of tyre enveloping behaviour, in a way that larger contact length means more pronounced low-pass filtering. Analysis of frequency content of response curves for different values of contact length, which can be regarded as the most appropriate indicator of tyre filtering properties, suggests that alteration of enveloping behaviour does not happen evenly with the change of contact length, but that it will be much more significant in certain regions of contact length gradient.

In this paper tyre contact length was mainly treated as suggested parameter of tyre enveloping model. Further task that has to be carried out within this scope is to assess level of dynamic fluctuations of tyre contact length, which is effect of deflection change due to dynamic wheel load. In that way it will be possible to conclude if it is necessary to include variable contact length into tyre enveloping model. Should it be possible to leave out this part of modelling approach, it would contribute significantly to the model simplification and therefore improvement of numerical efficiency.

## ACKNOWLEDGMENTS

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