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Motor Vehicles & Motors 2024

ECOLOGY -
VEHICLE AND ROAD SAFETY
- EFFICIENCY

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PREDGOVOR

U oktobru se na Fakultetu inženjerskih nauka Univerziteta u Kragujevcu tradicionalno održava skup istraživača i naučnika koji se bave proučavanjem motornih vozila, motora i drumskog saobraćaja. Od 1979. do 2004. godine održano je trinaest bienalnih MVM simpozijuma koji su 2006. prerasli u Međunarodni kongres MVM. Od tada je održano devet MVM kongresa, a oktobra 2024. godine Fakultet inženjerskih nauka je organizovao deseti međunarodni kongres MVM od 10. do 11. oktobra 2024. godine.

Na deseti kongres Motorna vozila i motori, MVM2024 dostavljen je veliki broj naučnih radova iz Srbije i inostranstva. Kongres tradicionalno podržavaju Ministarstvo za nauku, tehnološki razvoj i inovacije Republike Srbije, Univerzitet u Kragujevcu, Fakultet inženjerskih nauka i međunarodni časopis „Mobility and Vehicle Mechanics“.

Tema Kongresa MVM 2024 bila je „Ekologija – Bezbednost vozila i na putevima – Efikasnost“. Tokom ovog istraživačkog putovanja, učesnici su puno naučili kroz rad na različitim sekcijama, koje su pokrivale širok spektar tema u vezi sa inženjerstvom u automobilskoj industirji, od fundamentalnih istraživanja do industrijskih primena, naglašavaju interakciju između vozača, vozila i životne sredine i stimulišući naučnu interakcije i saradnju.

Međunarodni naučni odbor u saradnji sa organizacionim odborom izradio je podsticajan naučni program. Program je ponudio preko 54 prezentacije radova, uključujući predavanja po pozivu i radove u sekcijama. Prezentacije na ovom kongresu obuhvatile su aktuelna istraživanja u oblasti motornih vozila i motora sprovedena u 12 zemalja iz celog sveta.

Zadovoljstvo nam je bilo što su nam uvodničari bili profesor Emrulah Hakan Kaleli (sa Tehničkog univerziteta Yıldız, Turska), profesor Ralph Putz (sa Univerziteta Landshut UAS, Nemačka) i profesori Nenad Miljić i Slobodan Popović (sa Univerziteta u Beogradu, Srbija). Izazovi i rešenja u korišćenju vodonika kao goriva za motore sa unutrašnjim sagorevanjem, korišćenje aditiva nanoborne kiseline dodatog u motorno ulje, kao i evropska politika o budućoj mobilnosti na putevima su bile teme uvodnih predavanja.

Sigurni smo da je ovaj program pokrenuo živu diskusiju i podstakao istraživače na nova dostignuća.

10. Kongres MVM 2024. finansijski je podržalo Ministarstvo za nauku, tehnološki razvoj i inovacije Republike Srbije.

Zahvaljujemo se iskusnim i mladim istraživačima koji su prisustvovali i prezentovali svoju stručnost i inovativne ideje na našem kongresu.

Posebnu zahvalnost dugujemo članovima međunarodnog naučnog odbora i svim recenzentima za njihov značajan doprinos visokom nivou kongresa.

Naučni i organizacioni komitet Kongresa MVM2024

FOREWARD

In October, the Faculty of Engineering University of Kragujevac traditionally holds gatherings of researchers and academics who study motor vehicles, engines and road traffic. From 1979 to 2004, thirteen, biennal MVM Symposiums have been held and they grew into an International Congress MVM in 2006. Since then, ninth MVM Congresses have been held, and in October 2024, the Faculty of Engineering organized the tenth International Congress MVM from 10th to 11th October 2024.

A large number of scientific papers from the Serbia and abroad were submitted to the tenth Congress "MVM2024". Congress is traditionally supported by the Ministry of Science, Technological Development and Innovation of the Republic of Serbia, University of Kragujevac, Faculty of Engineering and the International Journal "Mobility and Vehicle Mechanics".

The theme of the Congress MVM 2024 was "Ecology - Vehicle and Road Safety - Efficiency". Along this journey we learned from the various sessions, which broadly cover a wide range of topics related to automotive engineering from fundamental research to industrial applications, highlight the interaction between the driver, vehicle and environment and stimulate scientific interactions and collaborations.

The International Scientific Committee in collaboration with the Organising Committee built up a stimulating scientific program. The program offered over 54 presentations, including key-note speakers and paper sessions. The presentations to this conference covered current research in motor vehicle and motors conducted in 12 countries from all over the world.

We were pleased to have professor Emrullah Hakan Kaleli (from Yıldız Technical University, Türkiye), professor Ralph Pütz (from Landshut University UAS, Germany) and professors Nenad Miljić and Slobodan Popović (from University of Belgrade, Serbia) as the keynote speakers, addressing Challenges and solutions in using hydrogen as a fuel for internal combustion engines, using nanoboric acid (nBA) additive added in engine oil, as well as European policy on future road mobility.

We are sure this program will trigger lively discussion and will project researchers to new developments.

The 10th Congress MVM 2024 was financially supported by the Ministry of Science, Technological Development and Innovation of the Republic of Serbia.

We would like to thank experienced and young researchers, for attending and bringing their expertise and innovative ideas to our conference.

Special thanks are due to the International Scientific Board Members and all reviewers for their significant contribution in the high level of the conference.

Scientific and Organizational committee of Congress MVM2024

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Motor Vehicles & Motors

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MASKING EFFECTS UNDER DUAL AXIS WHOLE BODY VIBRATION

ABSTRACT: The existence of masking effects for fore and aft vibration under two axial Whole-Body Vibration (WBV) broadband random vibrations of seated subjects was investigated. Subjects were exposed to two axis excitation in simulated driving condition. Initially, level of excitation was the same in the both direction. Subjects did not have the same sensation in both directions and they had to adjust equal level of stimulus sensation. In laboratory investigation of subjects sensitivity was conducted under varied parameters: level of excitation (0.55 ms^{-2} r.m.s., 1.75 ms^{-2} r.m.s. and 2.25 ms^{-2} r.m.s.) and seat backrest position (position K inclined 14° with respect to vertical axis and position S in vertical position without inclination). Masked Threshold (MT) for vibration in fore and aft direction was determined for r.m.s. head acceleration. Both parameters sitting position as well as level of excitation had impact on MT. Relationship between MT and level of excitation can be represented by linear regression model.

KEYWORDS: ride comfort, fore and aft vibration, subjective assessment, masked threshold, vehicle

INTRODUCTION

The driver and passengers are exposed to multi axial vibration in the vehicle under different driving conditions. The health, working capabilities and comfort of human in vehicles are influenced by different kind of vibrations, [4,7]. Behaviour of the human body exposed to whole body vibrations (WBV) were analysed a lot in reviewed literature. The influential parameters such as: direction of vibration, level of excitation, type of excitation, source of vibration, seat backrest inclination, position of human body, etc. were determined and investigated. Exact and detailed explanation of human body behaviour under random multi axis vibration did not give unique conclusions, [1,2,6,8] . Researchers are dealing with *intersubjective* and *intrasubjective* differences in subjects' responses. Authors [4,5,10] investigated transmission of broadband random vibration through human body by application of seat to head transfer function in order to develop human body model of driver and to reduce extensive and expensive subjective tests **Error! Reference source not found.**[10].

When human is exposed to multi axial WBV with equal excitations in all directions, sensation of vibration in different directions are not the same. In [4] subjects had to match equal sensation of fore and aft and vertical vibration. Analysis of obtained data was performed in frequency domain by application of Multi Input/Multi Output model in order to remove liner effect of single axial vibration. Conducted investigation involved both objective and subjective responses of subjects.

Vertical vibration in the vehicle is dominant. Fore and aft vibration of the backrest is one of the principal sources of the vibration in the vehicle. Sensation of fore and aft vibration with respect to vertical vibration with same excitation intensity showed masking effect which is well known in acoustics, [11,12].

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In the [13], vertical sinusoidal vibrations masking effects were investigated. The presences of the noise were investigated too. Frequency dependence of the absolute threshold was similar to the results in published references.

When human is exposed to multi axial WBV, vibration in vertical direction masks fore and aft vibration. In order to improve drivers working environment and ride comfort determination Masked Threshold (MT) and its influence on ride comfort must be performed. The influential parameters on MT should be determined and investigated.

The aim of the conducted laboratory study was to investigate MT of fore aft vibration under dual axis broadband random excitation. In the [12] MT was determined under sinusoidal stimulus that depended on frequency content of stimulus.

The frequency dependence of the MT is evident in reviewed references [11-13].

Acceleration of the head can represent the level of vibration transmitted through human body in sitting condition. The influence of sitting position, level of excitation on the fore and aft acceleration of the head will be analysed in the presence of broadband random vibration. Subjective assessment of equal sensation level will be taken into consideration.

METHODS

Subjects

Six subjects aged between 18 and 54 years, with mean age of 39.86 years (Standard Deviation SD=10.99), a mean stature of 1.79 m (SD=0.04) and mean weight of 79.43 kg (SD=14.21) participated in the experiment. All subjects were with no history of occupational exposure to vibration.

An electro-hydraulic motion simulator, used in experiment, was designed to provide the test bandwidth from 0.3 to 30 Hz, with very small (negligible) power for the frequencies over 20 Hz, with total loading mass of 200 kg, and to obtain vertical (Z) and horizontal (X) random excitations simultaneously, Figure 1. The investigators had to define frequency bandwidth and magnitude of excitation,[5,9].

First, subjects were exposed to dual axis WBV of equal amplitude in order to detect sensation level of WBV. After that, subjects were asked to adjust level of fore and aft excitation in order to have equal sensation to both vertical and fore and aft vibration.

Figure 1 Measurement equipment

Seat backrest angle (position K inclined 14° with respect to vertical axis and position S in vertical position without inclination) and excitation magnitude (0.55 ms^{-2} r.m.s., 1.75 ms^{-2} r.m.s. and 2.25 ms^{-2} r.m.s.) were varied, [3,4].

Each signal recording lasted 27.3 s and was repeated 4 times. Number of data points was 2048. Frequency domain was 0.037-37.5 Hz.

Acceleration on the head (H, Figure 1) of the subject was measured in fore and aft and vertical direction as well as on the seat buttock interface (S, Figure 1). In this investigation only signals of the head acceleration in fore and aft direction were analysed.

Analysis

Human body is more sensitive on vertical than on fore and aft or lateral vibration. Masking of vibration is reduction of perception of vibration in fore and aft or lateral direction. Vertical vibration masks sensation of fore and aft vibration, when they have the same level of excitation. In the vibrational environment, such as vehicle, with multi axial excitation, for example in the vehicle, vertical vibration masks vibration in the other direction.

Masked Threshold (MT) is threshold for the perception of the stimulus determined in the presence of another stimulus. In this case energetic masking is analysed. Root Mean Square (r.m.s) of the acceleration of the human body is measure of sensitivity on vibration.

Masked Threshold (MT) is expressed in decibels, [12]:

$$MT(dB) = 20 \cdot \log_{10}\left(\frac{a_{hA}}{a_h}\right) \quad (1)$$

where a_{hA} is amplified head acceleration in ms^{-2} r.m.s. and a_h is head acceleration in ms^{-2} r.m.s.

RESULTS

Accelerations of the head (index h) and on seat buttock interface (index s) are measured in fore and aft direction (X) and vertical direction (Z). Measured accelerations are not weighted according to ISO 2631/1 [7] in order to get raw correlation between human sensitivity on vibration and influential parameters of environment. In order to have the same sensation level between vertical and fore and aft broadband random vibration subjects adjusted level of excitation in the fore and aft direction.

Median of fore and aft r.m.s. acceleration measured on the head (XH) and seat buttock interface (XS) of subjects and their linear regressions lines for K seat backrest position are shown in Figure 2. Median of fore and aft r.m.s. acceleration measured on the head (XH) and seat buttock interface of subjects (XS) and their linear regressions lines for S seat backrest position are shown in Figure 3. The highest level of r.m.s. acceleration is on the seat in fore and aft direction (XS) with adjusted equal sensation of vibration. Level of acceleration of the seat in fore and aft direction is higher than in vertical direction. Non linearity of the seat-head system, with respect to level of excitation, is shown in Figure 2 and Figure 3.

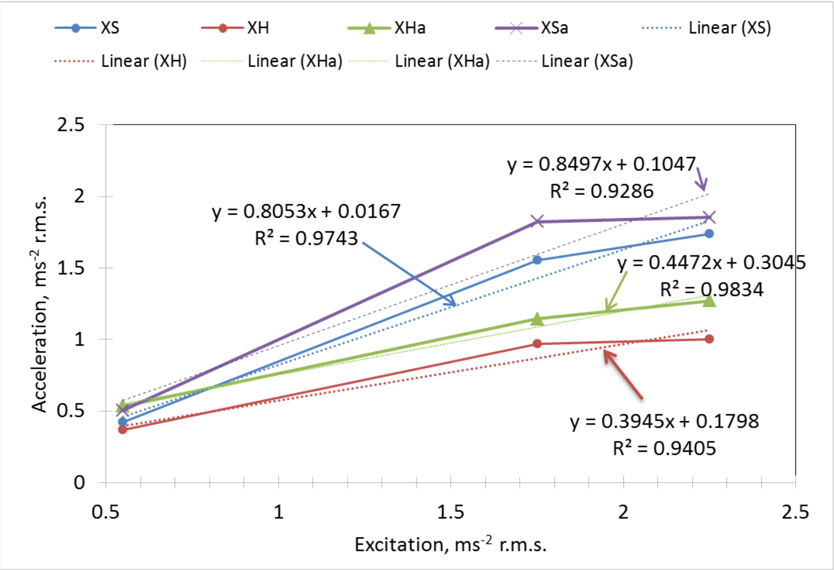

Figure 2 Median of fore and aft r.m.s. acceleration under dual axis WBV measured on the seat (XS) and head (XH) with K position of the seat backrest without subjective assessment and with subjective assessment (index a)

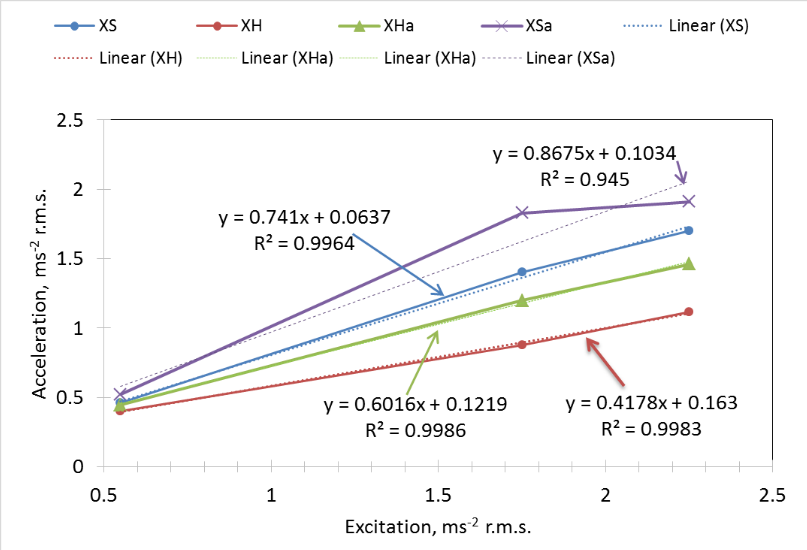

Figure 3 Median of fore and aft r.m.s. acceleration under dual axis WBV measured on the seat (XS) and head (XH) with S position of the seat backrest without subjective assessment and with subjective assessment (index a)

Linear regression model is applied on median accelerations of head and seat buttock interface in fore and aft direction, Figure 2 and Figure 3. Regression equations data are given in Table 1.

Coefficient of determination ($R^2 \geq 0.9286$, Figure 2, Figure 3 and Table 1) shows high level of positive linear correlation between median fore and aft acceleration of the head and seat buttock interface and level of excitation. Positive linear correlation between accelerations in fore and aft direction and excitation level exists when the subject`s assessments of equal sensation are analysed (index a).

Table 1 Linear regression model between median acceleration (y) of head (XH) and seat buttock interface (XS) and level of excitation (x) without and with subjects assessment (index a)

Acceleraiton	Backrest position	Linear regression equation	Coefficient of determination
XH	K	y = 0.4178x + 0.1630	R² = 0.9983
XS	K	y = 0.7410x + 0.0637	R² = 0.9964
XHa	K	y = 0.6016x + 0.1219	R² = 0.9986
XSa	K	y = 0.8675x + 0.1034	R² = 0.9450
XH	S	y = 0.3945x + 0.1798	R² = 0.9405
XS	S	y = 0.8053x + 0.0167	R² = 0.9743
XHa	S	y = 0.4472x + 0.3045	R² = 0.9834
XSa	S	y = 0.8497x + 0.1047	R² = 0.9286

Masked threshold for whole group of subjects is presented in Figure 4. Subjects were in sitting under K position of seat backrest angle.

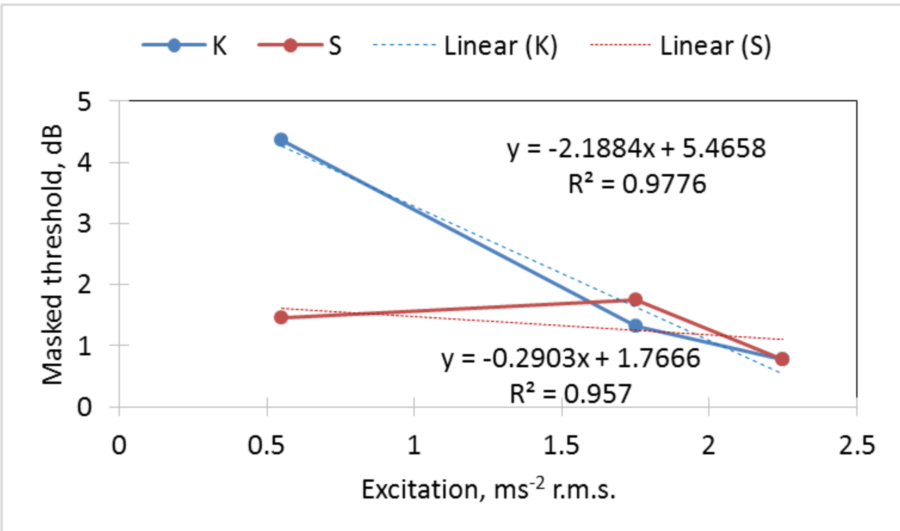

Figure 4 Masked threshold of fore and aft r.m.s. acceleration of the head under dual axis WBV with K position of the seat backrest

The influence of seat backrest angle on MT in fore and aft direction is presented in Figure 5. Obtained data are fitted by linear regression model. Masked threshold is influenced by excitation level and sitting condition. Negative linear correlation exists between MT and excitation level ($R^2 \geq 0.957$).

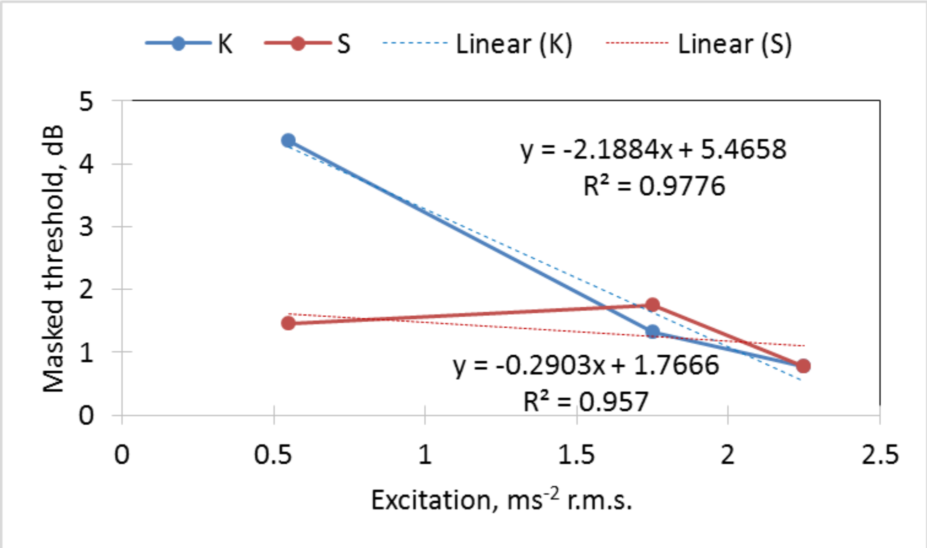

Figure 5 The influence of seat backrest position (K, S) on MT of fore and aft vibration assessed by subjects

CONCLUSIONS

Threshold for the perception of broadband random vibration in fore and aft vibration depends on initial excitation transferred to the human body and seat backrest position.

Masked threshold can represent subjective assessment of subject`s equal sensation level.

Linear regression model can be applied on MT of fore aft vibration respect to excitation level of broadband random vibration.

Performed analysis took into consideration vibration in fore and aft direction under two axial broadband random WBV. Investigation of MT respect to one axis WBV vs multi axial WBV should be conducted in the future.

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