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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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Determination of the seat-to-head transfer function and influencing factors on comfort under vertical random vibrations

ABSTRACT: This study aims to determine the seat-to-head transfer function (STHT) in subjects exposed to vertical random vibrations originating from a hydraulic pulsator, measured under laboratory conditions. The main objective is to examine how various anthropometric characteristics of subjects, such as Body Mass Index (BMI), sitting height, and age, influence the body's response to these vibrations. Ten female participants were exposed to uniaxial random broadband excitations in the vertical direction across three excitation levels (0.45 m/s², 0.8 m/s², and 1.1 m/s² r.m.s.) within the frequency range of 0.1 Hz – 20 Hz. Accelerometers were placed at the seat and the head to capture six acceleration signals in the x, y, and z axes at both locations. The results indicate that body mass, sitting height, and age significantly affect the STHT response, with higher BMI and sitting height correlating with distinct resonance characteristics. Notably, heavier subjects demonstrated lower resonance frequencies but higher maximum amplitude in the STHT frequency response. This research contributes to a better understanding of how individual anthropometric factors influence vibration transmission through the body, which is crucial for assessing comfort and designing ergonomically optimized seating in various vehicular and industrial environments.

KEYWORDS: artificial neural network, experimental measurements, vertical body vibration

INTRODUCTION

The study of vertical random vibrations and their effects on human comfort during seating is of paramount importance in various fields, including automotive design, aerospace engineering, and ergonomic assessments. As individuals spend significant portions of their daily lives seated, whether in vehicles, airplanes, or office environments, understanding how these vibrations transfer through the seat to the head is crucial for optimizing comfort and minimizing potential health risks. The concept of a seat-to-head transfer function serves as a pivotal element in quantifying how vibrations originating from external sources propagate through the body, impacting overall comfort and well-being [1].

Vibration exposure can lead to discomfort, fatigue, and even musculoskeletal disorders over prolonged periods of time. Therefore, accurately determining the seat-to-head transfer function enables engineers and designers to develop seating solutions that mitigate these adverse effects [2]. This study aims to explore the various factors influencing this transfer function. Factors such as anthropometric characteristics of the body, occupant posture, and vibration frequency range play significant roles in modulating the vibration transmission characteristics. By investigating how these elements interact, we seek to enhance our understanding of the complex dynamics involved.

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Contemporary literature explores the effects of vertical vibrations on the human body. In the study [3], researchers examined the behavior of the human head during vertical whole-body vibrations while seated in an upright position. They developed a detailed finite element model of a seated human that includes skeletal and muscular soft tissues to simulate the body's biomechanics. The vertical first-order resonant frequency and STHT were determined using modal analysis and the random response method, respectively. A significant resonance was detected around 5.7 Hz, a critical frequency that notably amplifies the head's response. Findings revealed that the maximum direct-axis response in the sagittal plane occurs in the posterior occipital region, with variations depending on head position. These results provide a theoretical foundation for assessing head response, developing models, and evaluating vibration comfort in seated individuals. Determining the seat-to-head transfer function and identifying key influencing factors are crucial for designing ergonomic seating solutions that enhance user comfort under vertical random vibrations. This research addresses existing knowledge gaps, offering insights that will inform the development of future seating technologies across various industries.

Another study [4] investigates the effects of posture and vibration magnitude on head motion during vertical seat vibrations. Thirty healthy male participants were exposed to random vibrations at magnitudes of 0.4, 0.8, and 1.2 m/s², over a frequency range of 1–20 Hz. STHT was analyzed for two postures: one with back support and another leaning forward on a table. Results highlighted notable cross-axis responses, with a resonance peak near 5 Hz in both postures, indicating significant head motion at this frequency. The study showed that increased vibration intensity causes a non-linear softening effect in muscle tension, especially with back support, whereas the body stiffens in a forward-leaning posture. These findings emphasize the role of posture and vibration magnitude in understanding vibration transmission and its implications for comfort and health.

In study [5], the impact of seat pan and backrest inclination on the transmission of vertical vibrations to a seated individual is explored. Researchers experimented with various seat pan angles (0°, 10°, and 20°) and backrest angles (0°, 15°, and 30°) using both foamed and rigid materials. Fifteen subjects were subjected to vertical random vibrations ranging from 1 to 15 Hz to measure seat transmissibilities. It was found that increasing the backrest inclination elevated the resonance frequencies in transmissibilities at both the seat pan and backrest, while changes in seat pan angle showed no significant effect. A foamed backrest's inclination increased peak transmissibilities, whereas a rigid seat pan or backrest reduced them at the opposite component. The study concluded that backrest inclination significantly impacts transmissibility more than seat pan inclination, influencing riding comfort and the dynamic interaction between the human body and the seat.

Overall, the determination of the seat-to-head transfer function and the identification of key influencing factors represent a critical step towards creating ergonomic seating solutions that prioritize user comfort under the influences of vertical random vibrations. This research aims to fill existing knowledge gaps, providing valuable insights that will guide the development of future seating technologies in various industries.

MATERIALS AND METHODS

Vibrations' effects on humans are studied in both operational and laboratory settings, with a particular focus on laboratory tests due to their ability to maintain a stable microenvironment (for instance, noise and thermal conditions) and ensure reproducibility of results. To facilitate excitation, a hydrodynamic pulsator, HP-2007, and an acquisition system, 01dB-Metravib PRO-132, were utilized. The HP-2007 pulsator is capable of providing excitation within a frequency range of 0.1-31 Hz and an amplitude of 0-50 mm, supporting a maximum load of 200 kg. It allows for both one-component and two-component excitation, offering various types of excitation, including harmonic (sine, triangular, or rectangular) and stochastic excitation.

Ten female participants, with mean age 31±1.63 years, height 170.4±3.4 cm, weight 63.8±9.67 kg, BMI 21.86±2.8, seating height 79.9±1.96 cm, underwent vertical uniaxial random broadband excitations at three levels (0.45 m/s², 0.8 m/s², and 1.1 m/s² r.m.s.) within a frequency range of 0.1 Hz to 20 Hz. Accelerometers were positioned at both the seat and the head to record six acceleration signals along the x, y, and z axes at each location.

Figure 1 describes the setup scheme of the measuring installation.

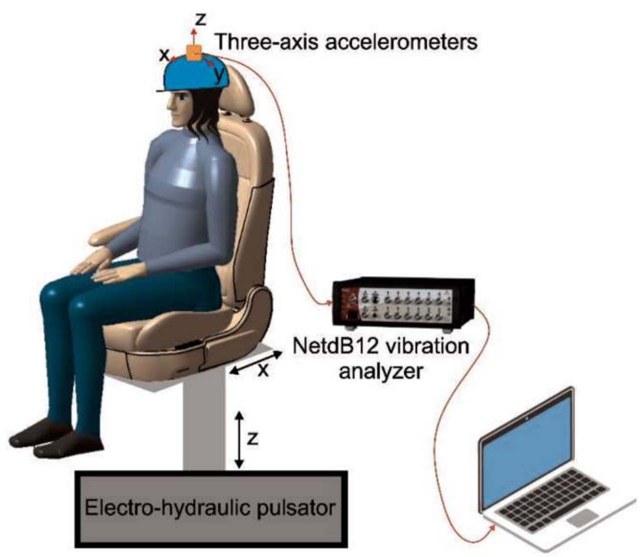

Figure 1 Schematic view of the measuring installation

The evaluation of the human body under whole-body vibrations utilizes biodynamic response functions, such as Mechanical Impedance (MI), apparent mass, and the STHT function. This paper focuses on the experimental determination of the STHT function, which is highlighted as a key area of study in subsequent sections. The STHT function is defined as the ratio of head acceleration to seat acceleration within the frequency domain [6]:

$$H(f)=Gxy/|Gxx| \quad (1)$$

where:
Gxy denotes the cross spectrum between the input and output,
Gxx refers to the autospectrum of the input signal.

The STHT function is a biodynamic metric that illustrates how incoming vibrations are transmitted through the body to various parts, specifically the head in this context. While the effects of various factors on mechanical impedance (MI) and apparent mass (AM) have been well investigated, the complexity in evaluating the response to head acceleration caused by the transmission of vibrations through the body still attracts much attention from researchers [7], [8], [9], [10].

RESULTS

The STHT function is analyzed in both horizontal and vertical directions, which are crucial as they reflect the head's movement in these orientations. Figures 2 and 3 present the averaged STHT functions for all participants along the horizontal and vertical axes under excitations of 0.45 m/s², 0.8 m/s² and 1.1 m/s², with a sitting posture of 90°.

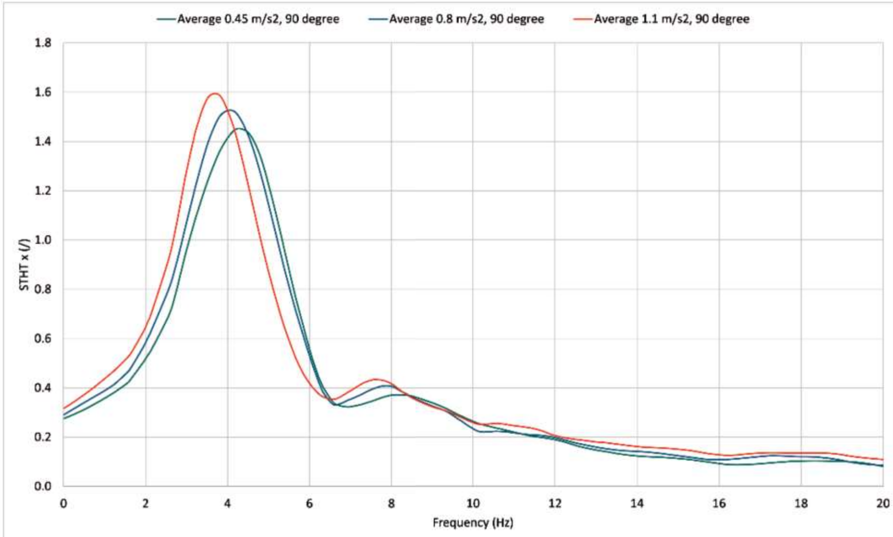

Figure 2 Averaged STHT functions in the horizontal direction

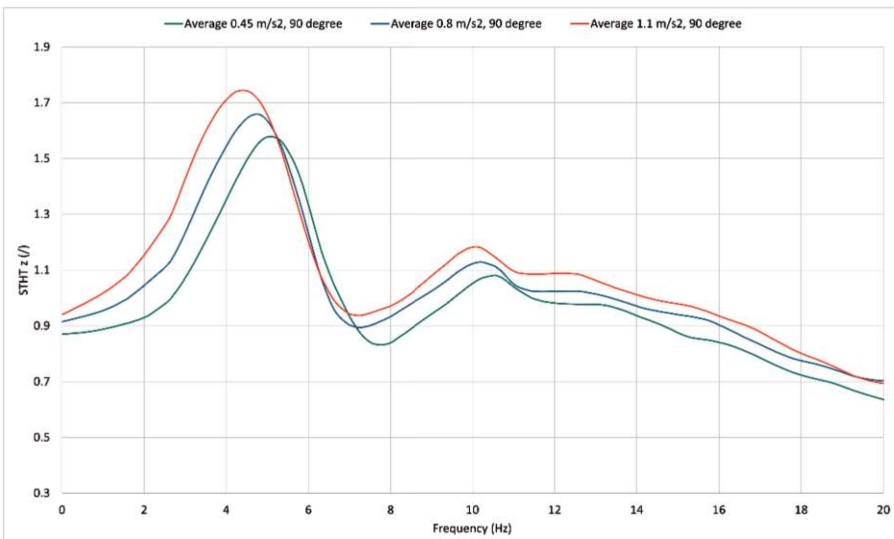

Figure 3 Averaged STHT functions in the vertical direction

The highest resonant frequency of 4.81 Hz (Figure 2) was recorded at an excitation of 0.45 m/s² r.m.s., with average STHT response amplitude of 2.04. At an excitation of 0.8 m/s² r.m.s., the highest resonant frequency was 4.56 Hz, recorded with average STHT response amplitude of 2.09. The lowest resonant frequency occurred at an excitation of 1.1 m/s² r.m.s., measuring 4.31 Hz with average STHT response amplitude of 2.17. From Figure 2, it can be concluded that as the excitation values increase, the average response amplitude of the STHT increases and the resonant frequencies decrease, indicating that the seat-driver system is nonlinear.

For the STHT function in the vertical direction, with a seat backrest inclination angle of 90° and an excitation of 0.45 m/s² r.m.s., the occurrence of the first resonant frequency was recorded later compared to the same seating angle in the longitudinal direction. Resonant frequencies in the vertical direction ranged from 5.27 Hz to 5.88 Hz (Figure 3).

Figure 4. shows the dependence of anthropometric characteristics (body mass index, height, years, body weights in a sitting position) and resonance frequency for female subjects exposed to different vertical excitation. A high correlation of BMI and resonance frequency R^2=0.864 can be observed for excitation of 0.45 m/s^2 r.m.s., while slightly lower values of R^2=0.698 and R=0.486 were recorded for excitations of 0.8 m/s^2 r.m.s.and 1.1 m/s^2 r.m.s., respectively. Body weights in a sitting position shows a correlation of R^2=0.609, R^2=0.598 and R^2=0.544 for given excitation values. The ranges of the age and the height of the subjects are relativelly narrow, to capture correlation with the results.

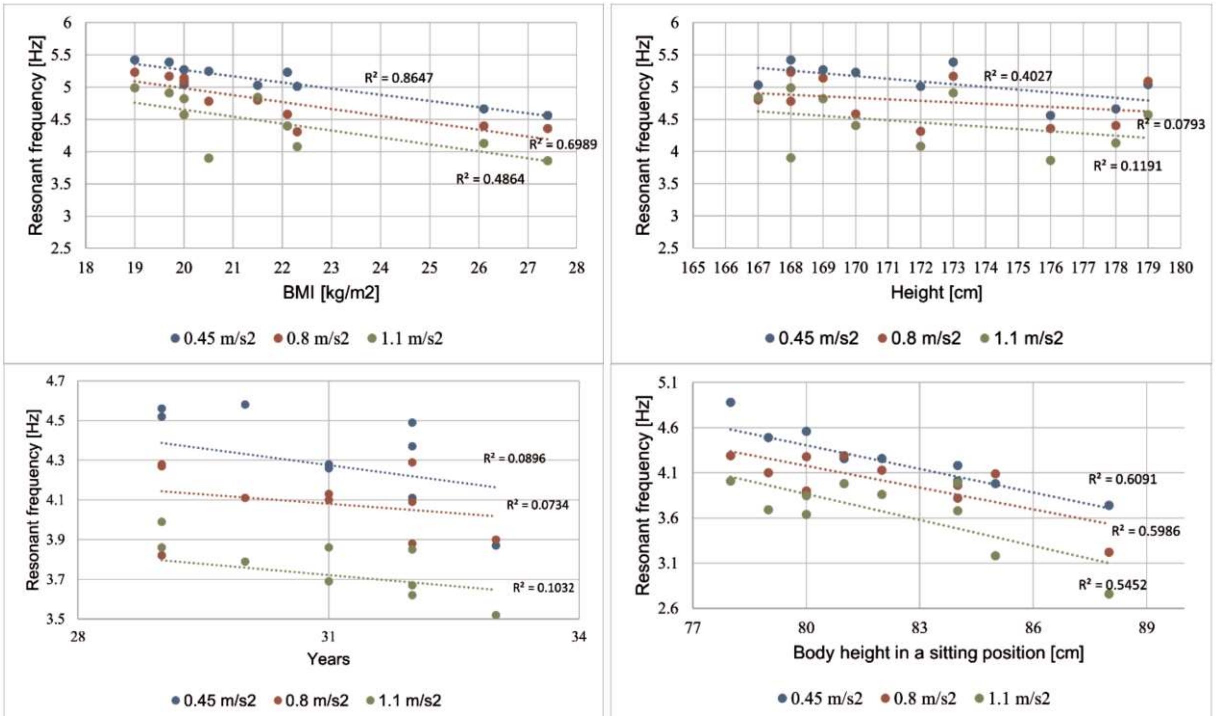

Figure 4 The influence of anthropometric characteristics of subjects on the resonance frequency for 10 female subjects during vertical excitation

CONCLUSIONS

This study successfully determined the seat-to-head transfer function in female subjects exposed to vertical random vibrations, highlighting the influence of anthropometric characteristics on vibration response. Using a hydrodynamic pulsator to simulate conditions, the research demonstrated significant impacts of body mass, sitting height, and BMI on the STHT response. Notably, results indicated that higher BMI and sitting height correlate with specific resonance characteristics, such as lower resonance frequencies but increased maximum amplitudes in heavier subjects. The STHT function, examined across different axes, showed a progressive increase in response amplitude and decrease in resonant frequencies as excitation values rose, evidencing the seat-driver system's nonlinear nature. Resonant frequencies in the vertical direction ranged from 5.27 Hz to 5.88 Hz, with distinct anthropometric influences. Analysis revealed a strong correlation between BMI and resonance frequency, particularly at lower excitation levels (0.45 m/s^2 r.m.s.). However, age and height showed lesser correlation, indicating other factors might drive resonance frequency changes. These insights are crucial for designing ergonomically optimized seating in various environments, contributing significantly to advancements in comfort and safety through a deeper understanding of how personal physical characteristics affect vibration transmission. Future research will be conducted on male subjects in order to make a comparison with female subjects and determine any differences in results.

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