VERIFICATION OF THE FUNCTIONALITY OF THE DIAGNOSTIC OF A SYSTEM WITH MANY ATTENUATION ELEMENTS

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Abstract

When carrying out a vibration analysis of a composite system, the point is mainly determining stiffness and attenuation between individual elements. The TVS method deals with this analysis in case that the elements are arranged linearly and oscillations predominate in one direction only. The frequency region analyzed by this system is between 5 and 180 Hz. The system consists of one vibrator, one strain gauge, and twenty accelerometers which are attached by means of double-sided adhesive tape to the analyzed structure. In this structural arrangement, also the precise location of the sensors and the actual values of the variable properties of the measured system make a difference to a certain extent. The content of this article is the verification of the TVS method for two basic methodology requirements, repeatability for an identical sample and resolution for two different samples, i.e. we determine the extent to which minor variations of the state of the measured system and small variations in the position of the sensor locations influence the results obtained using the TVS method.

Key words: attenuation, stiffness, diagnostics, verification of function.

INTRODUCTION

Although many works deal with oscillations of backbone elements, KELLER ET AL. (2010) and RAMIREZ ET AL. (2013), for example, this is usually the measurement of oscillations in such situation where the measured person actively makes a movement. The authors then get into such situation where the difficult definability of external stimuli leads to problems when interpreting the results. The closest measurement which is already made fairly as standard in the USA is the measurement of impedance (the applied force simultaneously with the acceleration caused) on the body of one vertebra. The method is applied also therapeutically in such a way that a frequency scan is used to find the resonance maximum of the vertebra concerned and vibration excitation is then applied to it. We do not know about any other complex investigative method which is carried out in such situation where the patient is inactive and thus the data are not made non-transparent. A part of our team has been dealing with the TVS method since 2003 and has published some preliminary results, comparing, for example, changes in the mechanical parameters of the spine while driving a car or while doing exercise (ZEMAN AND ZABLOUDILOVÁ, 2007).

The functional disorders of the musculoskeletal system are one of the most common causes of musculoskeletal pains. The functional disorders of the thoracic spine include faulty, impaired posture in this area (Fig. 1) and also a change in the method of making various routine movements (a change in the locomotive stereotype) and the reduction or limitation of the mobility of the thoracic spin (VÉLE, 1997).

It follows from the methodology that every method must be repeatable, i.e. that we have to obtain similar results when making more measurements on the same object. The second basic requirement is that we have to be able to tell two different objects apart. We try to verify both of these methodological requirements for the TVS method (JELEN ET AL., 2010). For this purpose, a series of experiments was conducted and two objects were measured in the following mode during this series.

The aim of this work is thus primarily verifying the stability of the results, and whether particular people are recognisable (distinguishable) with the aid of correlation coefficient, i.e. without use of any interpretation model.

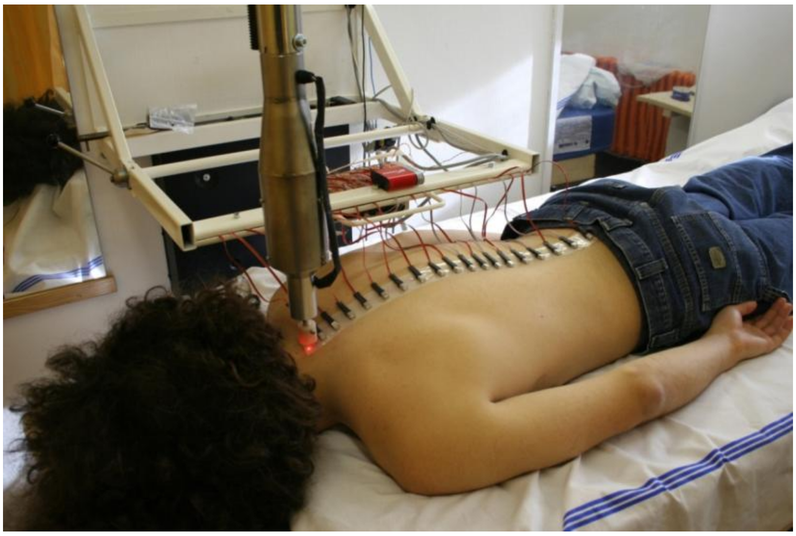

Fig. 1. – Measurement using the TVS method

MATERIALS AND METHODS

When the spin is excited using the Transfer Vibration through Spine method (TVS), see Fig. 1, the passive transmission of vibrations excited from the stimulated vertebra to the adjacent vertebrae and, for lower frequencies, a neuromuscular response occur. Sensing and evaluating the acceleration of vertebrae C7-S1 give us valuable information not only about the state of the intervertebral joints in the body, discs, ligaments, and adjacent musculature, but also about the functioning of the postural mechanism in individual vertebral segments (ZEMAN, 2006).

Twenty accelerometers were placed on the spine of a person lying prone. Each of them was attached to one vertebra from C7 to S1. An impactor was put on vertebra C7 and then L5. Mechanical pulses in the shape of a Gaussian curve with a half-width of 10 ms acted on the excited vertebra with a peak force of 10 N (JELEN ET AL., 2012*)*. As a result of this impact the spine started to move in a specific way. As the excited vibrations of the spine resulting from such impact have amplitude in the order of tens of micrometers, the movement was not measured directly, but the position was obtained by double integration of the measured acceleration (PANSKÁ ET AL., 2012).

After placing one of the objects in the test device, two measurements were made in sequence immediately without reattaching the sensors, which thus remained in the same places. Comparing the results of the two measurements, we are able to recognize the extent to which the micro variation of the system state between these measurements will influence the results obtained. After making these two measurements, we do the same thing on the second object. Comparing the results obtained in the case of the first object and the second object, we are able to determine whether the results enable us to tell the objects apart. After taking a pair of measurement on the second object, we return to the first object and make two measurements immediately in sequence again. However, it is basically necessary to reattach the sensors between the first measurement series on the first object and the second measurement series on the second object. Comparing the series thus gives us the opportunity to assess the extent to which the results measured depend on the position of the sensors. Now we make the second series of measurement also on the second object for the same reason. Then the third series on the first object and on the second object follows.

The evaluation takes place as follows: only the phase and the amplitude of the frequency just excited are determined using the signal measured by the accelerometers. As the frequency changes continuously from the lowest to the highest and back while measurement is made and this process is repeated three times, the spin is always measured six times at a frequency concerned. When evaluating, we always consider the average of the six values thus obtained, the ratio between the vertebra excited by amplitude, and the amplitude of the vertebra tested to be the result. This takes place for all measured frequencies, which gives us a spectrum of the transmission of vibrations from the exciting vertebra to the tested vertebra. Transmissions from vertebra C7 to vertebrae Th3 Th5, Th7, Th10, L2, and L4 were evaluated for this contribution. These calculations were made for the series of measurement on two probands described above.

The spectra obtained were compared as follows. Firstly, the coefficient of determination among all the obtained spectra for the vertebra concerned was determined, i.e. both for repeated measurements on the same volunteer and among the volunteers themselves. Secondly, the Shapiro-Wilk test of normality for the difference between the spectral values and the measurements compared was also carried out for all combinations. If the differences between the spectra have a normal distribution, it can be assumed that they consist of random influences only and not of systematic influences. The more the distribution of this difference is distant from the normal Gaussian distribution, the more the signal of the measurements compared changes systematically.

RESULTS AND DISCUSSION

Tab. 1. – Gives the coefficients of determination among all measurements made

	1x1	**2x2**	**1x2**	**1x1***	**2x2***	**2x2***
Th3	0.21	0.19	0.13	0.32	0.34	0.83
Th5	0.11	0.07	0.05	0.00	0.02	0.23
Th7	0.13	0.08	0.07	0.25	0.05	0.17
Th10	0.21	0.19	0.13	0.32	0.34	0.83
L2	0.14	0.08	0.07	0.09	0.02	0.08
L4	0.18	0.12	0.10	0.30	0.28	0.03

Here we can see that the coefficients of determination are always the smallest ones among any comparisons of the volunteers between each other. The second volunteer tested has coefficients of determination a little higher compared with its measurements, but the first volunteer is more similar to him himself. This comparison shows that the average coefficients of determination enable us to identify which measurement belongs to which of the probands. This meets the methodological requirements for the repeatability and sensitivity of measurement.

Tab. 2. – Shows the mean values of the Shapiro-Wilk test among all the measured results

	1x1	**2x2**	**1x2**	**1x1***	**2x2***	**2x2***
Th3	0.63	0.68	0.62	0.15	0.72	0.62
Th5	0.58	0.69	0.63	0.21	0.86	0.55
Th7	0.61	0.67	0.64	0.43	0.73	0.39
Th10	0.48	0.39	0.46	0.17	0.88	0.16
L2	0.68	0.63	0.66	0.55	0.80	0.52
L4	0.40	0.56	0.50	0.36	0.76	0.51

As the extreme p-value for all the cases mentioned is 10^{-6}, it is evident that the normality of the differential spectrum can be rejected in all cases. Using the values of the coefficients given in the table, it is nevertheless possible to assume relatively which differential spectra have their distribution of values more similar to a normal distribution than other. As you can see, it is found out for all the vertebrae that the differential spectrum calculated among the volunteers is the closest to a random distribution. A little less random distribution is for comparing the proband with him himself in the case of the first proband and the least random distribution is in the case of the second proband. The same results can also be surprisingly achieved using the Kolmogorov-Smirnov test of normality. These comparisons show that a systematic difference is mainly among the spectra of the volunteers, while individual measurements on the same volunteer show differences more corresponding with a Gaussian distribution.

According to the result of this experiment it seems that the results of earlier works are also consistent. E.g. for the work of KAMP ET AL. (2014) the point is confirmation of the results for the truck driver.

CONCLUSIONS

The purpose of this study was to evaluate the extent to which it is possible to rely on the uniqueness and, at the same time, on the repeatability of the spectra obtained using TVS. Volunteers of a similar phenotype and geomorphologic features were deliberately chosen for repeated measurements. Despite the high spectral similarity, it was shown that the mutual spectral similarity between the volunteers was always lower and less random than when repeated measurements on the same volunteer were compared.

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