Tomáš LACK
Juraj GERLICI
Vladimír HLAVŇA

THE VEHICLE COMFORT CASE STUDY

The paper relates closely to theoretical considerations of vehicle comfort assessment published in the journal Horizonty dopravy – special No. 2006 under the title „ Evaluation of Ride Comfort for Passengers". It can be understood as application of the mentioned theoretical considerations - as a case study. Influence of vibration on a standing and sitting person is assesed in the case study.

Keywords: *vehicle, ride comfort, passenger, measurement, assessment, weighting curves, index*

1. Introduction

The paper considers only that part of the comfort influenced by the dynamic behaviour of the vehicle. This part of the comfort is described as Ride Comfort or as Comfort. The European standard summarises the relevant works taking into account the effects on ride comfort for passengers from the vibration exposure measured on the car body floor (the simplified method for Mean Comfort evaluation), taking into account the vibration exposure measured on the interfaces (the complete method for evaluation) and taking into account the effects on Ride Comfort for passengers of discrete events (Comfort Discrete Events) and running on curve transitions (Comfort on Curve Transitions).

The quantification of Ride Comfort for passengers is performed through indirect measurements, i.e. measuring and post-processing the relevant parameters (accelerations and angular velocity, they were measured in the carbody). Other types of tests and evaluation, such as a direct test based on the direct assessment of the perceptions of tested passengers, and combined tests including both direct and indirect tests are possible as well, but they are not quantified in [1, 2]. The indirect measurements are classified as simplified or complete if the measurements are taken respectively on relevant points of the carbody floor, or also on the interfaces.

2. Case study

Comfort is a complex sensation produced during the application of oscillations and/or inertia forces, via the whole-body transmission caused by vehicle –frame movements. It is defined and measured through comfort indexes as [3, 4]:

⇒ **Mean comfort**: a mean feeling, continuously adjusted, as evaluated through a measurement following the procedures for comfort index N_{MV} and indexes N_{VA} and N_{VD}.

⇒ **Comfort on Curve Transition**: discomfort, due to a perceived curve entry or reverse transition, quantified by the recommended procedure indicated as comfort index P_{CT}.

⇒ **Comfort on Discrete Events**: discomfort, due to a perceived transient oscillation on a straight track, curves and curve transitions, qualified by the recommended procedure indicated as comfort index P_{DE}.

Two methods are available for the assessment of the passenger perception of Mean Comfort:

⇒ A simplified method based on measurement of acceleration on the floor (N_{MV})

⇒ A complete method based on measurement of acceleration at the interface between the passengers and the vehicle (N_{VA} and N_{VD})

There are measured accelerations in the directions of separate coordinate axe a_x, a_y, a_z. We know the measure frequency of f_n. On the base of the frequency we state a number of samples which we scan within the time interval of 5 seconds. At the scan frequency of 100 Hz we acquire 200 samples in five seconds. On the base of occurrence samples condition in 5 – second – time interval we divide the complete time of scanning (acquisition of samples) into 5– second – time intervals following each other. Each interval has in time strictly determined its begin T_1 and the end T_2.

In this way we have stated a number of data blocks. On the base of sampling frequency and time of 5 seconds we determine a number of scans which should be present in the given interval. For a further numerical elaboration it is necessary that this value be a multiple of two. In the case that it is not the above mentioned multiple we substitute it by the nearest higher value which is the multiple of two.

We do the Fast Fourier Transformation (FFT) for a file of data in each time interval defined by T_1 and T_2.

We do the computation *CAW* for the frequency range from 0.4 Hz to 80 Hz.

We apply the weighting filter w in dependence on the type of evaluation (floor, standing, seated).

$$C = w \cdot (Re, Im)$$

$$C^* = w \cdot (Re, -Im)$$

$$CAW = \sqrt{\frac{\sum_{f=0,4Hz}^{80Hz} \left| C \cdot C^* \right|}{2}} = \sqrt{\frac{\sum_{f=0,4Hz}^{80Hz} \left| w \cdot [\mathrm{Re}, \mathrm{Im}] \times [\mathrm{Re}, (-\mathrm{Im})] \right|}{2}} \quad (1)$$

In a statistical way we evaluate acceleration values modified by the weighting function in corresponding directions and we determine summating functions in histograms.

From the histograms for the values of 95% and 50% of the summating function we find out the acceleration values aWx_{95}, aWy_{50}, aWy_{95}, aWz_{50}, aWz_{95}.

$$Wx = W_d \cdot W_a = W_{ad}$$

$$Wy = W_d \cdot W_a = W_{ad}$$

$$Wz = W_b \cdot W_a = W_{ab}$$

$$Wd = W_c \cdot W_a = W_{ac}$$

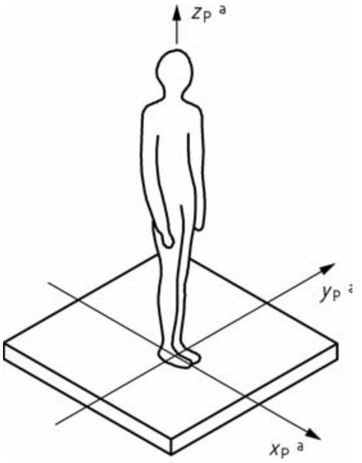

Fig.1 Standing position

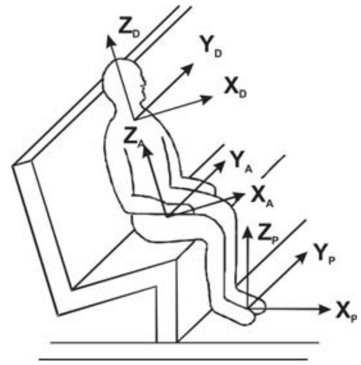

Fig.2 A sitting person

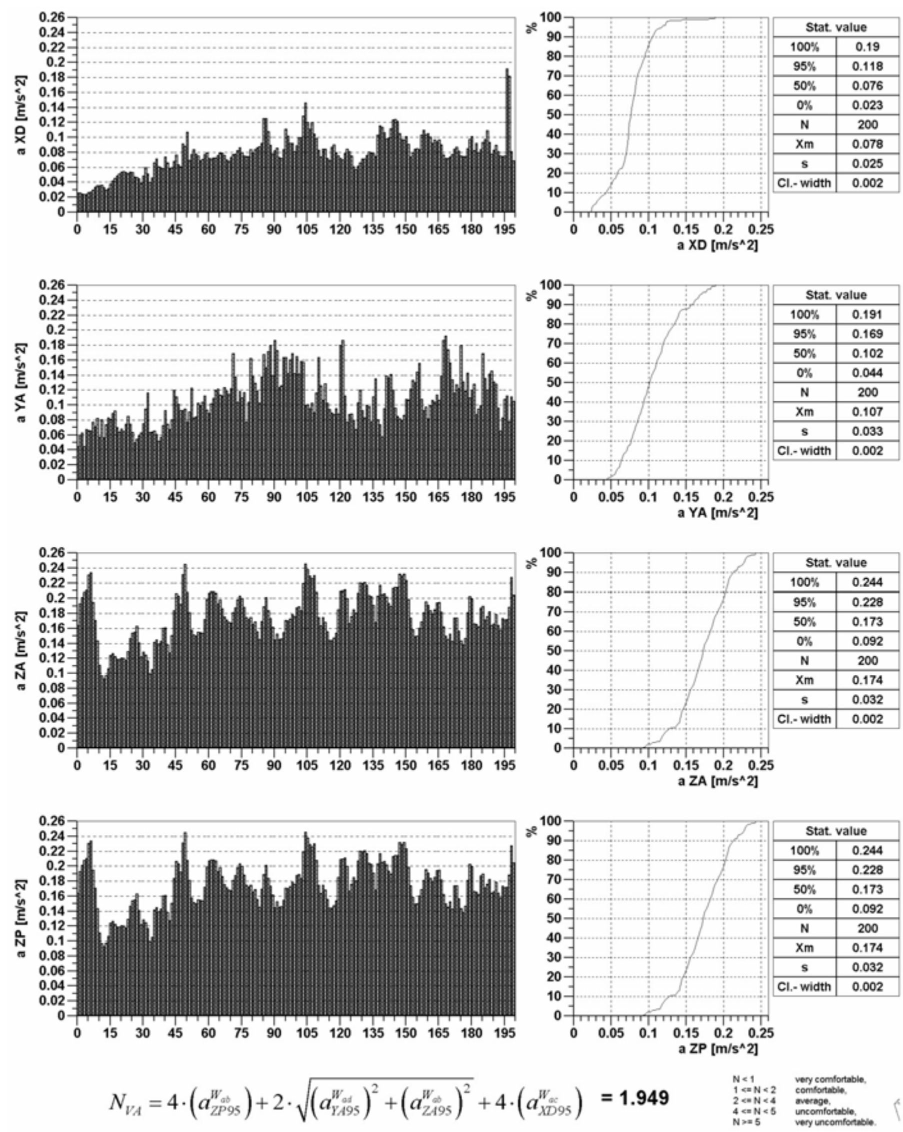

Fig. 3. The acceleration spectrum in the coordinates axe directions is depicted. The coordinate systems are connected with sitting person. The right graphs column are histograms with acceleration summating functions, the tables on the right side of the picture contain statistical values of measurements and assessments

aWx_{50}= acceleration value in the direction x multiplied by the weighting function Wx at 50% quantile of the summating function.

We state the final values of ride comfort indexes for passengers from the following formulae.

Floor: N_{MV}

$$N_{MV} = 6 \cdot \sqrt{aWx_{95}^2 + aWy_{95}^2 + aWz_{95}^2} \qquad (2)$$

The other record in accordance with the figure depiction:

$$N_{MV} = 6 \cdot \sqrt{\left(a_{XP95}^{W_{ab}}\right)^2 + \left(a_{YP95}^{W_{ad}}\right)^2 + \left(a_{ZP95}^{W_{ab}}\right)^2} \qquad (3)$$

A standing position: N_{VD}

$$N_{VD} = 3 \cdot \sqrt{16 \cdot aWx_{50}^2 + 4 \cdot aWy_{50}^2 + aWz_{50}^2} + 5 \cdot aWy_{95}^2 \qquad (4)$$

The other record in accordance with the figure depiction:

$$N_{VD} = 3 \cdot \sqrt{16 \cdot \left(a_{XP50}^{W_{ab}}\right)^2 + 4 \cdot \left(a_{YP50}^{W_{ad}}\right)^2 + \left(a_{ZP50}^{W_{ab}}\right)^2} + 5 \cdot \left(a_{YP95}^{W_{ad}}\right) \qquad (5)$$

For sitting position: N_{VA}

$$N_{VA} = 4 \cdot aWz_{95} + 2 \cdot \sqrt{aWx_{95}^2 + aWy_{95}^2} + 4 \cdot aWd_{95}^2 \qquad (6)$$

The other expression

$$N_{VA} = 4 \cdot \left(a_{ZP95}^{W_{ab}}\right) + 2 \cdot \sqrt{\left(a_{YA95}^{W_{ad}}\right)^2 + \left(a_{ZA95}^{W_{ab}}\right)^2} + 4 \cdot \left(a_{XD95}^{W_{ac}}\right) \qquad (7)$$

Tab.1 Comfort scale

N<1	*Very comfortable*	*4≤N<5*	*Uncomfortable*
1≤N<2	*Comfortable*	*N>5*	*Very uncomfortable*
2≤N<4	*Medium*		

3. Conclusion

The aim of comfort evaluation procedures by the indirect method (acceleration measurements) and by statistical evaluation is to achieve a concrete number, a comfort index which, when doing the analysis, takes into consideration the quality of the couple vehicle /track and it is not influenced by subjective feelings of individual passengers.

Vehicle properties from the point of view of comfort have an essential influence on the reliability of vehicle parts which are placed on the vehicle –frame.

4. References

[1] Ahokas J., Kosonen S.: *Dynamic Behaviour of Tractor-trailer Combination during Braking*, Biosystems Engineering 2003/86 (LF 1537-5110)

[2] DIN V ENV 12299:1999 Fahrkomfort für Fahrgäste, Messung und Auswertung.

[3] Knothe, K., Wille, R., Zastrau, W., B.: *Advanced contact mechanics – road and rail.* In: Vehicle system dynamics 2001, Vol.35, No4-5, pp. 361-407. Swets & Zeitlinger 2001..

[4] STN. Železnice. Jazdný komfort cestujúcich. Meranie a vyhodnotenie. STN P ENV 12299. 73 6361. Národná predbežná norma preložená z nemeckého originálu Bahnanwendungen- Fahrkomfort für Fahrgäste – Messung und Auswertung, Februar 1999. Apríl. 2001

****

The contribution was created within the framework of the project No. 1/3169/06 and in the project No. 1/2116/05, which is supported by the Scientific Grant Agency of the Ministry of Education of the Slovak Republic and the Slovak Academy of Sciences.

****

Ing. Tomáš LACK, Ph.D.
Doc. Dr. Ing. Juraj GERLICI,
Prof. Ing. Vladimír HLAVŇA, Ph.D.
University of Zilina
Universitna 1, 010 26 Žilina, Slovakia
e-mail: Tomas.lack@fstroj.utc.sk
e-mail: Juraj.gerlici@fstroj.utc.sk
e-mail: Vladimir.Hlavna@fstroj.utc.sk