EAN 2012
50th annual coference on experimental stress analysis

Experimental Evaluation of New Conception of Cab and Seat Vibrations Suppression

Jiří Blekta[1], Iva Petríková[2], Bohdana Marvalová [3]& Aleš Lufinka[4]

Abstract: One of the most important problem of coal mining by bucket wheel excavators is how to minimize influence of vibrations on driver´s body. Experimental and numerical research was aimed to vibrations suppression and a new cab and seat mounting of wheel excavator was designed. A suitable possibilities of cab suspensions were investigated to minimize driver body vibrations and to decrease influence of mining process to drivers health. After optimization one concept was chosen. A new methodic of measured data evaluation was created for using in excavators as well as in laboratory. The new concept of dynamic seat absorber were designed also. To investigate the spatial vibrations suppression, an experimental device has been used – a platform with six degrees of freedom which enables measured signal realization in laboratory.

Displacements, velocities and accelerations of the series of points on a driver body were determined by optical measuring technique - by dynamic measuring system PONTOS. The signal recorded before and after optimization were used and the effect on the driver body response was evaluated.

Keywords: vibrations; minimize; non-contact measurement

1. Introduction

The project solved in Department of Applied Mechanics in Technical University of Liberec was focused on the minimization of vibrations of bucket-wheel excavator cabin. The details of the machine Schrs 1320 working in Doly Nastup Tusimice are shown in [1].

An inappropriate cabin mounting was one of the main problem of the machine causing high level of cabin vibrations. Vibrations are excited by bucket wheel operation and were increased by rigid joints of outrigger, console and cabin frame. Therefore, operators were exposed to high level health-endangering vibrations.

The new frame of cabin suspension was designed on the basis of many experiments and simulations [2, 3]. The previous cab suspension on four air springs was replaced

[1] *Ing. Jiří Blekta, Ph.D.; Department of Applied Mechanics, Technical University of Liberec; Studenstká 2, 460 01 Liberec,Czech Republic; jiri.blekta@tul.cz*
[2] *doc. Ing. Iva Petríková, Ph.D.; Department of Applied Mechanics, Technical University of Liberec; Studenstká 2, 460 01 Liberec,Czech Republic; iva.petrikova@tul.cz*
[3] *prof. Ing. Bohdana Marvalová,CSc.; Department of Applied Mechanics, Technical University of Liberec; Studenstká 2, 460 01 Liberec,Czech Republic; bohda.marvalova@tul.cz*
[4] *Ing. Aleš Lufinka, Ph.D.; Department of Design of Machine Elements and Mechanism, Technical University of Liberec; Studentská 2, 460 01 Liberec, Czech Republic; ales.lufinka@tul.cz*

by three cable hangings. This enable cabin movement in three degrees of freedom - two horizontal directions and one torsion movement about vertical axis. The result of this improvement was the decreasing of vibration transmission from the cabin frame to the cabin floor in both horizontal directions. Vibration minimization in vertical direction was realized by a mechanism with dynamic absorber under the driver seat.

According to subjective drivers' feelings, vibrations in horizontal directions were considerably decreased. This was also verified by measuring on the cabin floor. The vibration level was decreased 10 times on an average. The effect of new cabin suspension on human body during mining process was measured by the set of sensors. Accelerometers were placed also on the cabin mount and on the cabin floor. The signals of sensors were enregistered and processed.

2. Experimental

The signals measured on the cabin floor were introduced to the experimental equipment - platform with six degrees of freedom - to reproduce cabin behaviour in laboratory. This platform is shown in Fig. 1 and described in detail in [4].

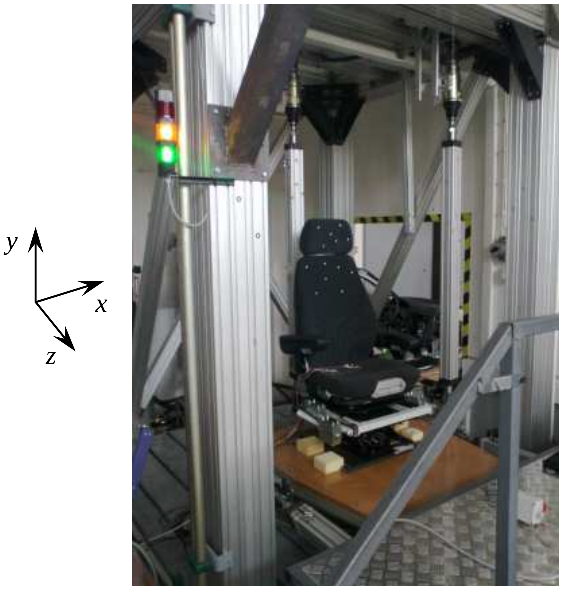

Fig. 1. Platform with six degrees of freedom.

The platform is able to reproduce general spatial movement of real body with respect to platform characteristics, i.e. maximum angles of ball joints or maximal engine velocities. The platform is used to simulate real conditions in laboratory. In this case real data from 2 three-dimensional accelerometers mounted on the cabin floor are integrated to simulate cabin movement. These data are recomputed in simulation model to signals for each one of six platform engines. In the next step, interactive simulation of platform motion is run to prevent possible collisions of platform desk in real experiments.

3. Vibration measurement of human body.

The PONTOS system of GOM based on dynamic photogrammetric method was used for measuring vibrations of human body. This method is well suited to measuring large displacements. These displacement-based approaches allow three-dimensional (3D) coordinates of an object (within the field of view) to be tracked by using digital images obtained at more known positions in space. Furthermore, surface preparation is generally required for this technique; dynamic photogrammetry tracks high-contrast. Circular targets were applied to a test object identifiable features within an image. During post processing of the recorded images, image processing is done to correlate similar points in one image to another tracking ellipses, thereby identifying dynamic changes to the structure of interest. Coordinates, displacements, speeds and accelerations of every point are determined in every time step by the image processing in PONTOS software. Some parameters of used PONTOS 5M system are presented in Table 1.

Table 1. Parameters of PONTOS 5M system

Parameter	Value
Camera resolution [*pixel*]	2448 x 2050
Frame rate [*Hz*]	up to 15
Measuring Area	from cm^2 to m^2
Accuracy	up to 0.001 *mm* (depending on measuring area)
Number of measured markers	unlimited

4. Measurement

The reference point - self-adhesive markers were applied to measured object - a human body. The support composite tube with a pair of high-resolution cameras was fixed on the wall in front of the platform. A good visibility of all points from the both cameras was provided. The three groups of markers were used: reference markers (placed on the stationary part of the platform), markers on the head and markers on the torso of figurant sitting on the operator seat. Each group contained several markers to get detailed information about movement of particular human body part.

Three figurants of different weight were measured. Parameters of these persons are summarized in the Table 2.

Table 2. Persons available for measurement

Person	Weight [kg]	Height [m]
1	82	1.81
2	93	1.76
3	101	1.86

The frequency of snapshot was 15 frames per second. The seat was excited by two different signals for each person. The first signal used (signal A) was enregistered before the change of the cab suspension. The length of this signal was 50 *s*. The intensity of vibration of signal A is comparable in all directions. The second signal (signal B) was enregistered after the installation of the new cabin damping device. The length of the signal was 33 *s*. The values of signal B indicate lower levels of vibrations in horizontal directions, approximately the same level of vibrations in vertical direction (due to signal A). The measurement with original and new signals was three times repeated for each person to get valid data.

5. Results

Measured data were analyzed for each person individually. At first we focused on human body behaviour during seat exciting by signal A in comparison with signal B. Then it was analyzed human body behaviour in dependence on its weight, i.e. efficiency of suggested cabin suspension adjustment for drivers of different weight.

Displacements, velocities and accelerations of each point were compared for body movement excited by both signals. RMS values were calculated and compared to each other. The values of acceleration of human torso in the horizontal directions z and x receiving from measuring for excitations by signal A and B are shown in Table 3. Let´s consider average acceleration of the torso under excitation of body by signal A is 100%. The average values of acceleration from all torso points are in the columns 2, 4. The acceleration of signal B expressed as a percentage of the signal A is enrolled at columns 3, 5.

Table 3. Acceleration of human torso in horizontal direction *z* and *x*

Person	z direction		x direction	
	RMS - acceleration of torso [%] - signal A	RMS - acceleration of torso [% of column 2] - signal B	RMS - acceleration of torso [%] - signal A	RMS - acceleration of torso [% of column 4] - signal B
1	100.0	67.5	100.0	84.5
2	100.0	70.4	100.0	89.4
3	100.0	69.2	100.0	87.3

Trajectories of individual points placed on human body is shown in Figure 2. From this trajectories were computed speed and acceleration for individual point. The position of one of the measured points named "torso_point_1" is shown in the same figure. This point was chosen only for presentation purposes. Results was computed from all points. The acceleration in the both horizontal directions for exciting signal A, resp. signal B represented by point "torso_point_1" is shown in Figure 3, resp. Figure 4. Some anomalies in graphs (e.g. in Fig. 3 nearly time 20 s) are caused by bad visibility of some points during measuring.

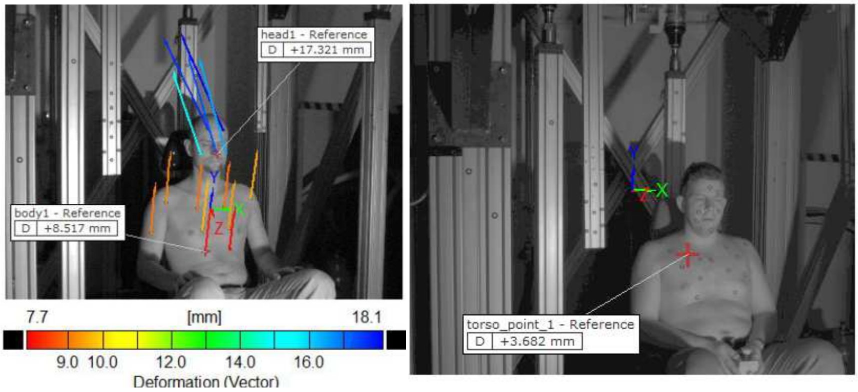

Fig. 2. Trajectories of individual points and position of "torso_point_1"on the measured human body.

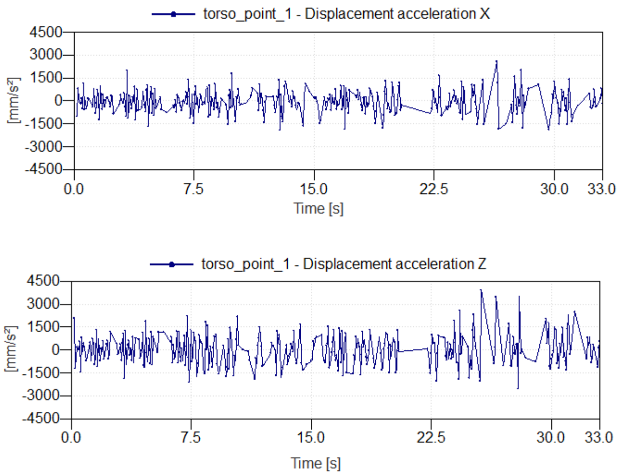

Fig. 3. Acceleration of "torso_point_1" in lateral and longitudinal direction - signal A.

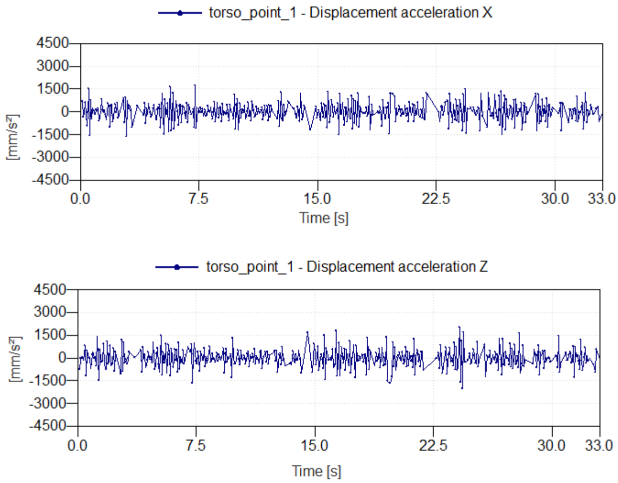

Fig. 4. Acceleration of "torso_point_1" in lateral and longitudinal direction - signal B.

6. Conclusion

Main aims of this paper was to show non-contact method to measure vibrations of human body. Optical method is alternative to conventional contact methods based on placing sensors (e.g. accelerometers) to individual parts of body. One of the advantages of this method is a flexibility of measurement preparation. Therefore measuring procedure can be reduced to shorter time.

The results of PONTOS method measurement demonstrate the efficiency of the new conception of cabin suspension. It is evident that driver´s horizontal acceleration was suppressed. The most important improvement is diminution of vibration in longitudinal direction. Similar results are available for torso and head movement.

This paper was supported by the grant from Ministry of Trade and Industry of the Czech Republic under Contract Code MPO FT-TA5/102 .

References

[1] Blekta, J., Mevald, J. & Lufinka, A., "Reduction of the Vibration Effects Actuating In General Direction On Colliery Machine", in *Proceedings of EAN 2009*, Sychrov, 2009 (Technical University of Liberec, Liberec, 2010), pp. 43-47. ISBN 978-80-7372-483-2.

[2] Blekta, J & Lufinka, A., "Simulation of a Bucket Excavator Cab Real Movement", in *Proceedings of EAN 2009*, Sychrov, 2009 (Technical University of Liberec, Liberec, 2010), pp. 38-42. ISBN 978-80-7372-483-2..

[3] Blekta, J., Mevald, J., Petríková, I., Petříček, J., Lufinka, A., "A New Conception of Bucket Wheel Excavator Cab and Seat Mounting", in *Vibration Problems ICOVP 2011 - The 10th International Conference of Vibration Problems*, Praha, 2011 (Spinger, Liberec, 2011), pp. 649-656. ISBN 978-94-007-2068-8.

[4] Blekta J., Mevald J., Petríková I., "Evaluation of spatial vibrations using a platform with 6 degrees of freedom", in *Proceedings of EUCOMES 08*, Cassino, 2008 (Springer, Cassino, 2011), pp. 577-583. ISBN 978-1-4020-8914-5.