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RESEARCH OF MULTI-DEGREES VIBROISOLATION OF AN OPERATOR IN WHEEL-EXCAVATOR

Peter Bocko[1], Josef Mevald, Jiří Blekta, Iva Petríková[2] Aleš Lufinka[3]

Key words: human body vibration, vibroisolation, wheel-excavator, seat, polyurethane foam

Abstrakt:
This paper contains the research and development project overview of seat and cab vibroisolation in wheel-excavator. The aim of this project is to reduce the operator vibrations. Project includes the theoretical analyses of HBV, laboratory measurements of the seats, additional horizontal and vertical suspensions, polyurethane seat foam tests, field cab vibration measurements, wide range of multi-body simulations, prototype design including the FEA structural analyses and planed prototype production and measurements.

1. Introduction

This paper contains the project overview of multi-degrees vibroisolations of operator in wheel-excavator. The project started on 6/2008 and the finish is planed to 12/2010. This project is solved in cooperation with IDIADA CZ a.s., Technical university of Liberec (TUL), Severočeské doly a.s. (SD - brown coal producer), Ministry of Industry and Trade of the Czech Republic, Prodeco a.s. (wheel-excavators producer), Research institutes – VÚTS Liberec, VÚHU Most, Czech National Institute of Public Health and Slovak academy of science. The aim of this project from R&D point of view is to achieve the know-how in the field of design and optimization of multi-degrees vibroisolation - cab and seat vibroisolation, polyurethane seat foam. The aim from realization point of view is to design, manufacture and test the multi-degrees vibroisolation for SchRs 1320 cab.

2. Problem description and phases

2.1. Theoretical analyses

First project phase contains the theoretical analyses of multi-degrees vibroisolations of wheel-excavators and criteria definition for human body vibrations HBV (interpretations of vibrations). Used standards ČSN ISO 2631-1, 2002/44/ES, 258/2000 Sb., 148/2006 Sb. The research was focused to cab suspension design (1st level), seat suspension – seat mechanism (2nd level), seating foam design and parameters (3rd level) and biomechanical, physiological and psychological effects to human body vibrations. The seat and cab vibrations are influenced by many factors. The main factors are bucket wheel rotation (digging forces), boom rotation movement (horizontal movement for continual digging), forward and backward movement of excavator or boom (cutting depth), vertical boom position, vertical cab position, and so on. The eigenfrequency is affected by speed of digging movement and by position of excavator parts.

[1] **Ing. Peter Bocko, PhD.**, IDIADA CZ a.s., Ptácká 131, 293 01 Mladá Boleslav, Czech Republic, Tel.: +420 326 736 858, e-mail: peter.bocko@idiada.cz
[2] **Doc. Ing. Josef Mevald, CSc., Ing. Jiří Blekta, Ph.D., Doc. Ing. Iva Petríková,Ph.D.**, Technical University of Liberec, Department of Engineering Mechanics; Studentská 2, 461 17 Liberec, Czech Republic, e-mail: josef.mevald@vslib.cz, jiri.blekta@tul.cz, iva.petrikova@tul.cz
[3] **Ing. Aleš Lufinka**, Technical University of Liberec, Department of Design of Machine Elements and Mechanisms; Studentská 2, 461 17 Liberec, Czech Republic, e-mail: ales.lufinka@vslib.cz

2.2. Analysis of the seats and additional seat vibroisolations

The laboratory tests are realized on 6 degrees testing platform (Fig. 1), which can simulate harmonic and also real movements (vibrations) measured in real cab. 3 types of seats (1 with mechanical and 2 with pneumatic suspensions), 2 types of horizontal suspensions and 2 types of additional vertical absorbers were tested with passive loading (40, 60, 80kg) and biomechanical loading (70, 85, 100kg). Together with laboratory tests the multi-body simulations with MSC Adams including LifeMOD for HBV were realized (Fig. 2).

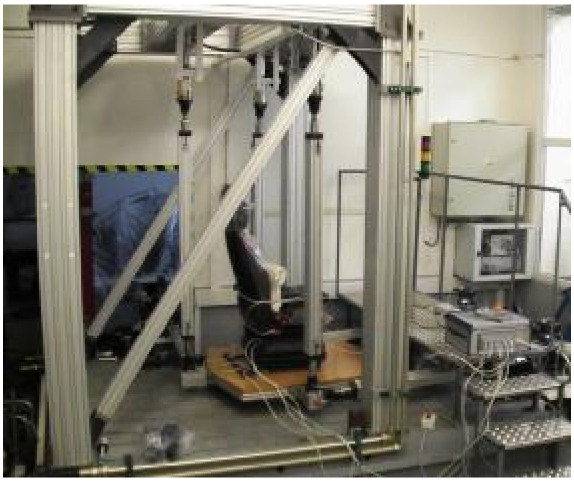

Fig. 1 *6 degrees testing platform (TUL)*

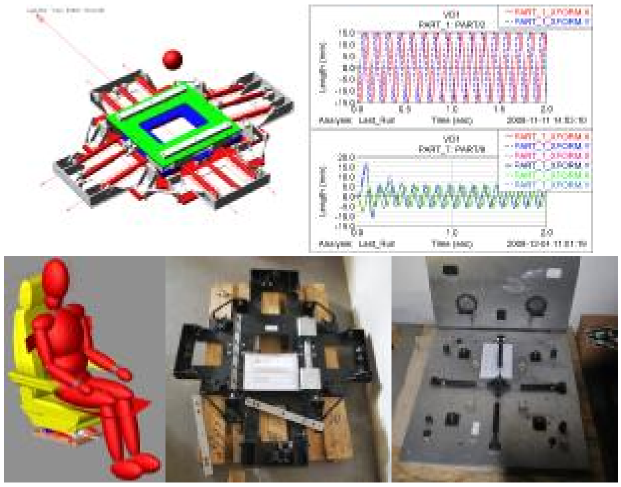

Fig. 2 *Horizontal suspensions and MSC Adams simulations*

2.3. Polyurethane seat foam

The purpose of this phase was to create the model of damping forces of dynamically loaded specimens of polyurethane foam dependent on its density. 6 types of 100x100x50mm polyurethane seat foams test specimens were tested by Instron ElectroPuls 3000 (Fig. 3). MDI with density 50, 55, 60 kg/m3 and TDI with 40, 45, 50 kg/m3 (Fig. 4). [1]

Fig. 3 *Instron ElectroPuls 3000 and thermal chamber (TUL)*

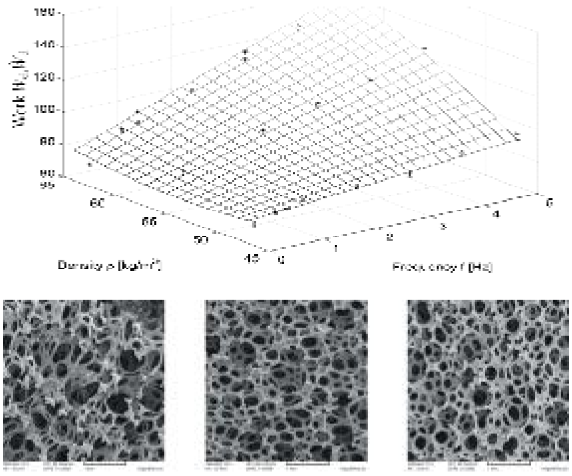

Fig. 4 *Power-density-frequency graph and PU structure for different density*

2.4. Current cab vibroisolation

The most important part of this phase was the field tests of three types of wheel excavators SchRS 1320, KU800 and K 2000 in Severočeské doly a.s. The accelerometers for vibration measurements (Fig. 5) were placed on console (left – position 1-3), frame (left – position G – 3D gyroscopic accelerometer), cab deck (right – position 1-3) and seat (right – position S). Dewetron DEWE-5000 was used in combination with MEMS accelerometers. The acceleration results were transformed to displacements and used for laboratory tests in 6 degrees testing platform and for multi-body simulations in MSC Adams. Partial aim of this phase was to analyze the currently used cab vibroisolations. 2 basic types are actually in operation – pneumatic springs+dampers and mechanic springs+dampers. The catalogue of potencial vibroisolations was proposed for all types of wheel-excavators and SchRS 1320 was choosing for practical application of planed vibroisolation design.

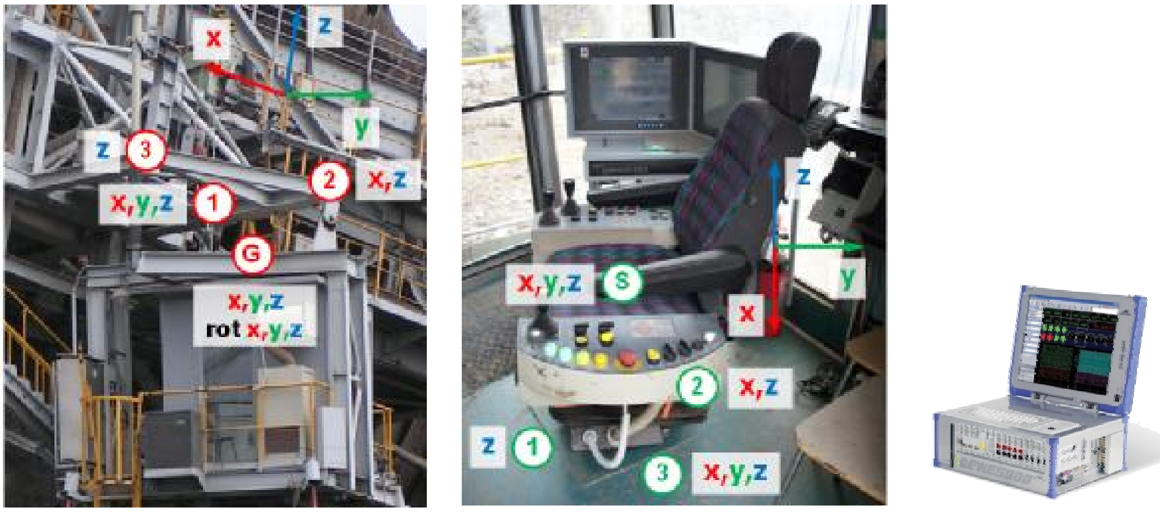

Fig. 5 *Field vibration measurements – SchRS 1320*

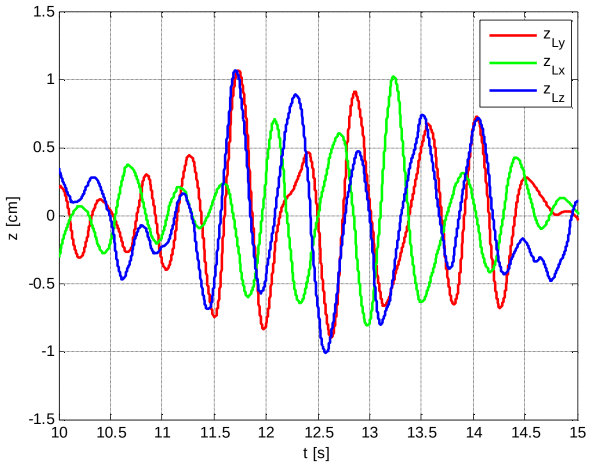

Fig. 6 *Cab floor displacements – axes x, y a z*
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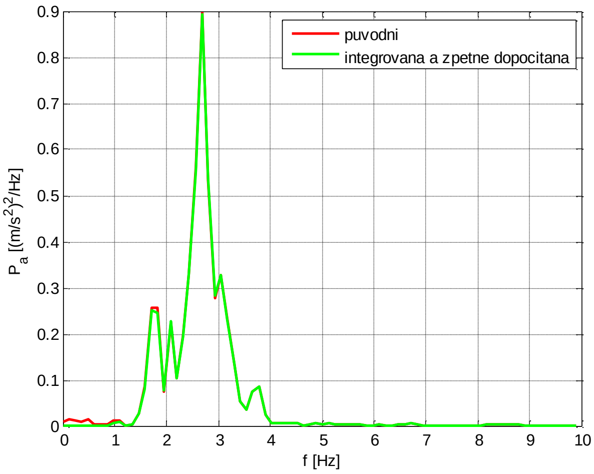

Fig. 7 *PSD acceleration comparsion – measurement (red) and displacement (green)*

2.5. Design of multi-degrees cab vibroisolations

All types of potential vibroisolations from catalogue were analyzed as 2D (Working Model) and 3D (MSC Adams) using the simple harmonic and real signals. The best damping was achieved by parallelogram design (Fig. 8) – cab is hang on the frame by 3 wire rope fittings or alternatively by 3 bars with spherical bearings. The frame acceleration (Fig. 8 right-top) of the frame generated by real signal is reduced in the cab (Fig. 8 right-bottom). The resonance frequency depends on the length of the bars (2m corresponds to 0,35Hz) [2].

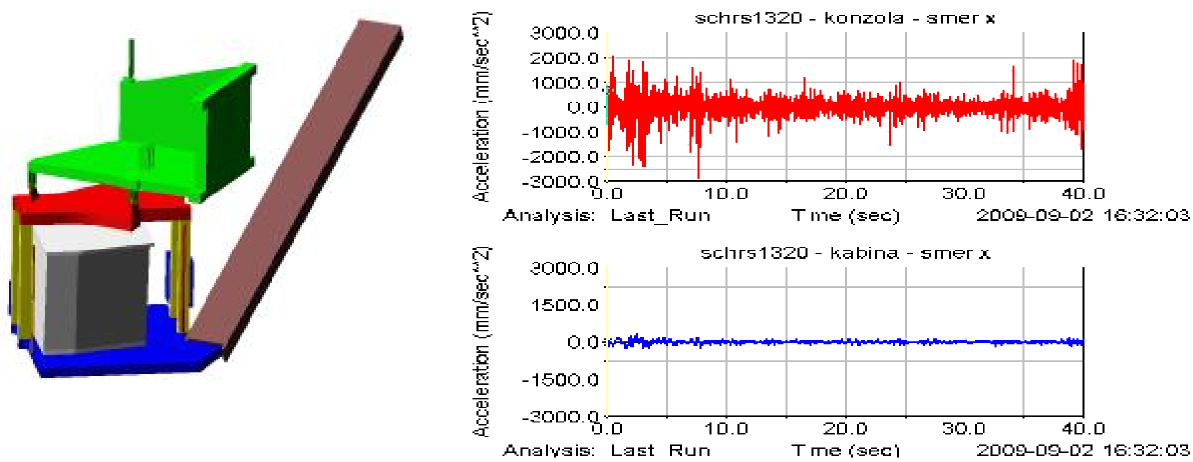

Fig. 8 *MSC Adams simulation model and results – acceleration reduction*

2.6. Practical application of multi-degrees vibroisolation

The parallelogram design selected in previous phase was processed to final manufacturing documentation. The Beta CAE Ansa+Meta, Nastran and Abaqus were used for FEA structural analyses (Fig. 10). Additionally the adjustable shock absorbers, adjustable stop shock absorbers and rubber backstops were designed for potential damping regulation. Parallelogram design can eliminate only the horizontal vibrations, which have the most adverse effects to the human body. Vertical vibrations will be damped by seat suspension.

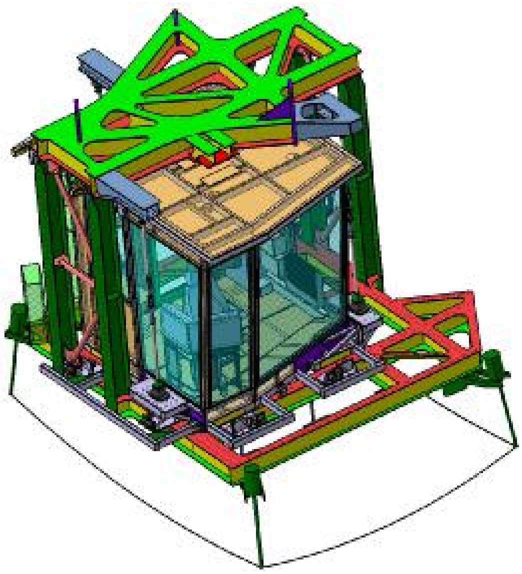

Fig. 9 *3D model of prototype (Catia)*

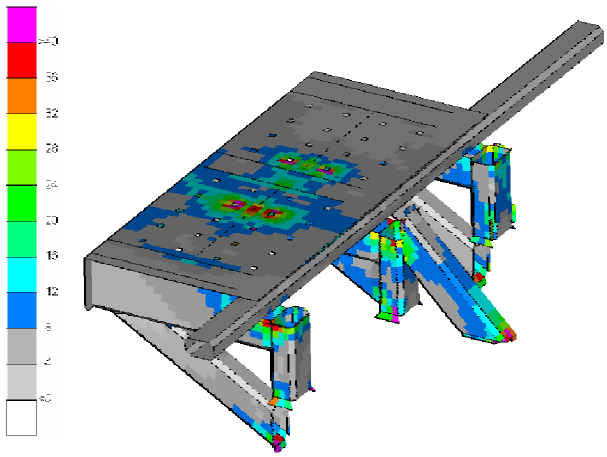

Fig. 10 *FEA (Beta CAE Ansa, Meta and Abaqus)*

2.7 Measurements and optimization of the prototype

The prototype realization is planned in September 2010. The detailed durability study before and after the reconstruction is also part of this project [3]. After that the long term monitoring of vibrations will be necessary. For this purpose the Dewetron DEWE-101 independent data logger including the HBV postprocessing will be used.

3. Conclusion

For the duration of this project much information, partial results and skills about wheel-excavators and its vibrations were acquired. The innovation aspect of this project is to reduce the HBV of operator with new types of vibroisolation. The presumption is that this prototype can dramatically reduce the cab vibrations. Project includes wide range of activities e.g. data acquisition with DEWE-5000 and DEWE-101 (acceleration and strain gages) in the field and laboratory, CAE – MBS in MSC Adams and FEA in Abaqus and Nastran, CAD – design and technical documentation (Catia) and production of prototype.

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