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FORCE AND ACCELERATION MEASUREMENT ON MOBILE CAR PARTS

MĚŘENÍ SIL A ZRYCHLENÍ NA POHYBLIVÝCH ČÁSTECH AUTA

Abstract

The contribution deals with task of combined force and vibration measurement on the difficult mobile objects as the car doors. There are described the examples of instrumentation for these measurement (force hammer, piezoelectric accelerometers, laser sensor of speed displacement). There was used measurement instrumentation set B&K with program support LabPulse. The paper shows testing results of the back car door lock close forces as an example of combined force-vibration task.

Abstrakt

Příspěvek pojednává o úlohách kombinovaného měření síly a vibrací na složitých mobilních objektech jako jsou dveře automobilu. Jsou zde popsány příklady instrumentace pro tato měření (siloměrné kladívko, piezoelektrické akcelerometry, laserový senzor rychlostní pohybové změny). Bylo zde využito přístrojové vybavení od firmy B&K s programovou podporou LabPulse. Příspěvek ukazuje výsledky testování zavíracích sil zámku zadních dveří automobilu, jako příkladu kombinované silově-vibračních úlohy.

1 INTRODUCTION

Department of Control Systems and Instrumentation in VŠB-TU Ostrava has set-out suitable instrumentation for difficult dynamical measurement and its co-workers have required knowledge and experience for its effective using [Smutný & Tůma, 2008]. Dynamical measurement of position and motion parameters of mechatronic elements and systems (speed and acceleration, displacement – position), eventually their force-moment quantity (force, torque) be part of important mechanical designer tools, especially in automotive industry [Sapinski, 2004, 2006]. Actual problem of development mechanical design and testing car back door there are identification of static and dynamic forces, which take effect in the exercise long time test [Palenčár, Kureková & Halaj, 2007].

2 MEASUREMENTS OF DYNAMICAL FORCES WITH CONVERSION OF ACCELERATION

Direct dynamic forces measurement on the mobile objects is relatively difficult challenge. We can use for its elegant solving the equivalence operation between force actuating in the specific test point of mobile object and parallel vibration measurement (for instance acceleration) by this way dynamic force excited [Brandt, .. & Tůma, 2005], [Korzeniowski & Pluta, 2008].

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Instrumentation and other condition for measurement:

1. Composition of instrumentation, included the Analyzer PULSE (9 channels), notebook HP with program system LabShop Pulse (B&K), again 2 pieces of miniature acceleration sensors (with huge acceleration range - max 1000 g) and impulse impact force hammer.
2. Specification and detail solving measurement case in the program LabShop Pulse for used instrumentation, ranges setting, parameterizations of measurement task (2 sensors of acceleration, 1 force sensor), sample frequency setting, time record, possibility of next data modification from the point of frequency.
3. Piezoelectric accelerometers installation on the vehicle body under catch staple of door latch and accelerometers calibration (L Mass, H-Mass).
4. Measurement of time courses from impulse hammer and together from two accelerometers. These courses of a function there were deducted from the peak force and two accelerations values and all calibration and tested measurement there were use with sampling frequency f=16 356 Hz.
5. From these data records there was computed transfer acceleration-force coefficient by function

$K_F = \frac{a}{F}$, where a is acceleration [m.s^{-2}], F is force from impulse hammer [N].

3 FORCE MEASUREMENT INSTRUMENTATION

On the next figures we can see measurement conditions, instrumentation and final results. On the Figure 1 we can see basic schema of force measurement on the mobile objects with impact impulse force hammer. On the next Figure 2 there is measurement stand for vibration measurement with B&K analyzer at the *Testing locks cars department*.

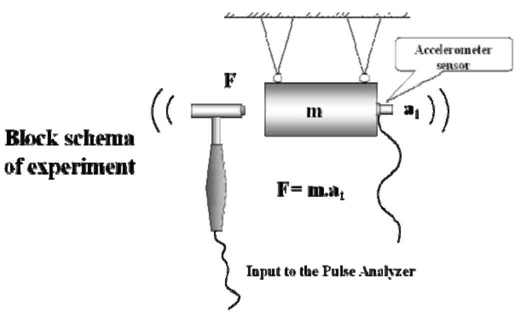

Fig. 1 Force measurement on the mobile objects with impact force hammer

Fig. 2 Measurement stand for vibration measurement with B&K analyzer

On the Figure 3 we can see accelerometers calibration with transformation between force and acceleration by Impact Hammer in the BMW car. The placement of accelerometer (L-Mass) on the vehicle body under catch staple of door lock there is on the Figure 4.

On the Figure 5 we can see laser measurement systems for angle and displacement measurement OMETRON, which were used for noncontact measurement of impact door speed. On the Figure 6 there is impact force hammer (2302-5 Delta Tron Impact Hammer, ENDEVCO Model Hammer , type 2302-5, force *F*=4498 N, frequency range 8 kHz).

The laser vibrometer complete the equipment for non-contact vibration measurements. Unlike traditional contact vibration transducers, laser-based vibration transducers, or laser vibrometers, require no physical contact with the test object.

Fig. 3 Accelerometers calibration with transformation between force and acceleration by Impact Hammer

Fig. 4 Accelerometer placement on the vehicle body under catch staple of door lock

Fig. 5 Laser measurement systems for angle and displacement measurement OMETRON

Fig. 6 Impact force hammer, ENDEVCO

Remote, mass-loading-free vibration measurements on targets that are difficult or impossible to access are typical examples of applications where a laser-based vibration transducer would be the natural choice. Furthermore, the ability to incorporate advanced, miniaturised, optical mirror systems together with the laser source provides automated scanning measurements, where a high number of measurement points can be measured consecutively. Non-contact vibration measurements with very high spatial resolution are possible with such a scanning system and can lead to significant improvements in the accuracy and precision of experimental modal models.

4 OVERVIEW OF EXPERIMENTAL RESULTS

On the next few figures we can show results from the huge experimental measurements (calibration, force measurement in different speed of back car doors locking). On the Figure 7 we can see repeated calibration in the centre of lock eye – force course as a representative charts with stabile force course (5 repeated measurements).

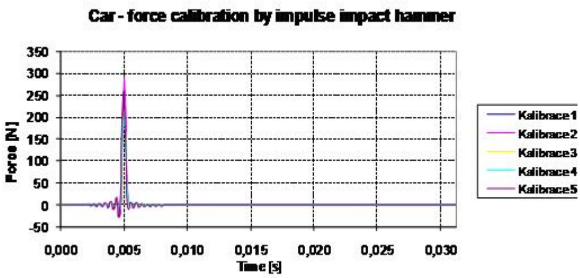

Fig. 7 Car – repeated calibration in the centre of lock eye – force course F [N] (representative charts with stabile force course)

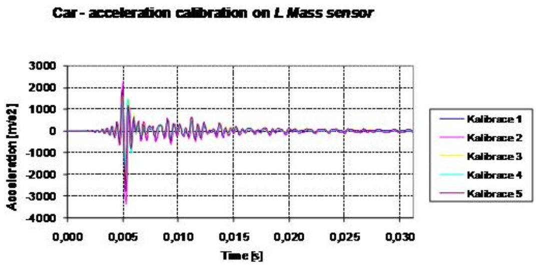

Fig. 8 Car – repeated calibration in the centre of lock eye – corresponding acceleration time courses on L Mass sensor.

On the Figure 8 there is repeated calibration in the centre of lock eye – corresponding acceleration time courses on L Mass sensor (5 repeated measurements).

On the next Figure 9 we can see all measurement files from 11 repeated exams on the basic bare metal BMW car body without of windows. There are very similar courses of accelerations with different impact speeds loping of fifth doors.

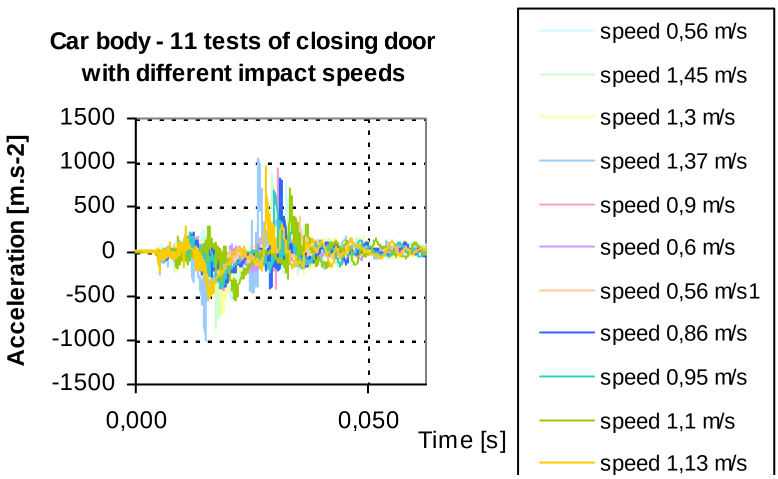

Fig. 9 Car BMW Car – repeated calibration, corresponding acceleration time courses on L Mass sensor, with different impact speeds loping doors (corresponding maximal forces F=178 N)

We can see the first touch of door lock with lock eye (time 0,015 – 0,025 s, max locking force cca *F*=130 N) and there are also the force reverse incidences (max force *F* =164 N). On the Figure 10 and Figure 11 we can see the final results from measurement on the car BMW by two acceleration sensors (L Mass – on the vehicle body) and (H Mass on the moving mobile car back door). There were repeated 30 experimental measurements and on the figures are only two interesting time shift courses for different impact speeds.

For comparison we can see on the Figure the situation with personal car Škoda Octavia – acceleration measurement on sensor s H Mass from the maximal high spot level with the additional closing force of driver.

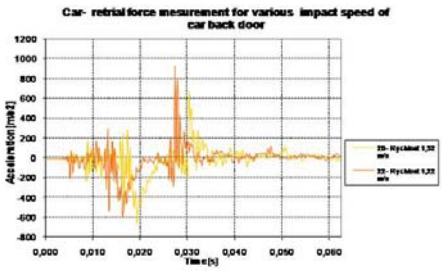

Fig. 10 Car BMW – acceleration measurement on sensor L Mass in high impact speeds loping doors - 1,22 and 1,32 m/s

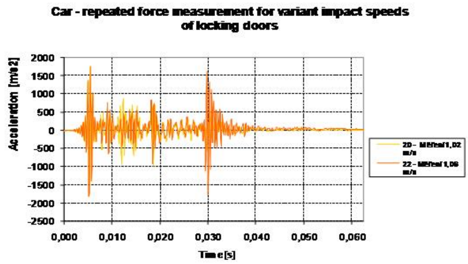

Fig. 11 Car BMW – acceleration measurement on sensor s H Mass in high impact speeds loping doors - 1,22 and 1,32 m/s

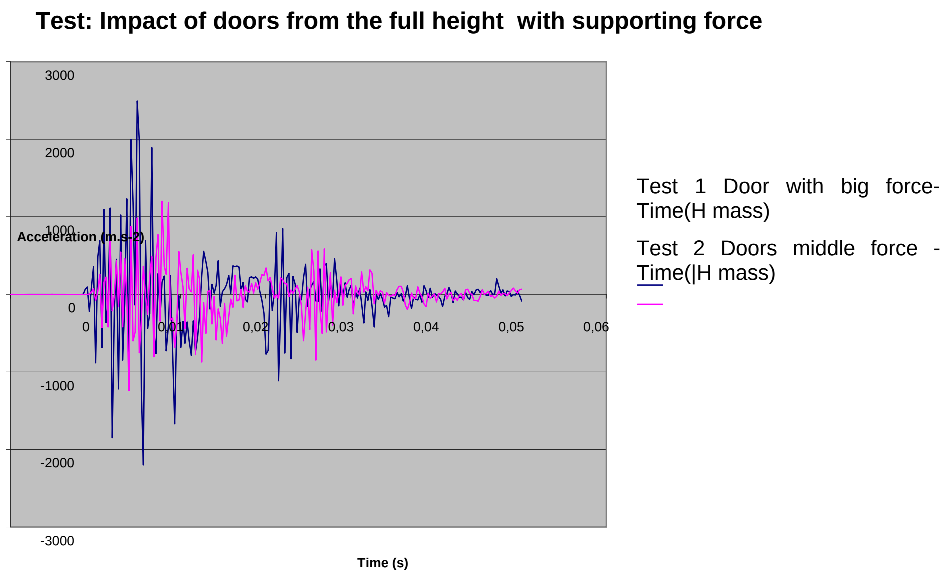

Fig. 12 Car Škoda Octavia – acceleration measurements on the sensor s H Mass from the maximal high spot level with the additional closing force of driver

5 CONCLUSION

Experimental measurement by top instrumentation B&K demonstrated good ability for detail identification of dynamic acceleration parameters and from these derivative forces in selected point of car lock, in different edge conditions (variant design of door lock, varying impact elevation). By the comparison of acceleration time courses in the car (BMW, Skoda Octavia) we can unambiguously say, that from these chart we can see basic influence and hunting resonance of vehicle body. Methodology and instrumentation for these difficult experimental tasks give good base for experimental services of Control Systems & Instrumentation Department on TU Ostrava.

Department of CSI has set-out suitable instrumentation for difficult dynamical measurement and its co-workers have required knowledge and experience for its effective using. Actual problem of development mechanical design and testing car back door lock there are identification of static and dynamic forces, which actuating in the exercise long time test.

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7 REFERENCES

[1] BABIUCH, M. & ŠKUTA J. Application for MEMS Components Testing. *Transactions of FME VŠB-TU Ostrava, Mechanical Line vol. LIII*, 2007, No. 1525, pp. 1-6. ISSN 1210-0471.

[2] BRANDT, A., LAGO, T., AHLIN, K. & TŮMA, J., 2005. Main principles and limitations of current order tracking methods. In *Proceedings of MAC-XXIII: A conference and exposition on structural dynamics*. January 31 – February 3, 2005, Orlando, Florida (USA), ISBN: 0-912053-89-5

[3] KORZENIOWSKI R. & PLUTA J. 2008. Investigation of Transient States of the Hydraulic Power Unit Cooperating with the Servovalve. *Transactions of FME VŠB-TU Ostrava, Mechanical Line vol. LIV*, 2008, No. , pp. 1-6. ISSN 1210-0471.

[4] PALENČÁR R., KUREKOVÁ E., HALAJ M., 2007. *Meranie a metrológia pre manažérov.* Bratislava: STU. Vyd. 1. 2007. ISBN 978-80-227-2743-3.

[5] SAPINSKI B. 2004. *Linear Magnetorheological Fluid Dampers for Vibration Mitigation: Modeling Control and Experimental Testing.* Cracow (Poland): AGH University of Science and Technology Press. Monograph 128. 2004. ISBN-

[6] SAPINSKI B. 2006. *Magnetorheological Dampers in Vibration Control.* Cracow (Poland): AGH University of Science and Technology Press. 1. Edition. 2006. ISBN-

[7] SMUTNÝ, L., TŮMA, J., KOČÍ, P., ŠKUTA, J. & JURÁK, M. 2003. Research Laboratory of Noise and Vibration Diagnostics at the Department of Control Systems and Instrumentation. In *Active Noise and Vibration Control Methods.* Krakow (Poland) : AGH Krakow, 2003, p. 54 (Abstract Proceedings). Full paper 6 pp. [CD ROM Proceedings]. ISBN 83-916516-6-5.

[8] SMUTNÝ, L. & TŮMA, J. 2006. *Měření dynamických sil zámku dveří automobilu.* Ostrava: VŠB-TUO, kat. 352. 2006. Technická zpráva pro firmu XY, Kopřivnice. 24 s.

[9] SMUTNÝ, L. & TŮMA, J. 2008. *Measurement of back car door close forces*. Ostrava: VŠB-TUO, 2008. Technical Report HS 352801. 30 p.

[10] SMUTNÝ, L., TŮMA, J., KOČÍ, P., ŠKUTA, J. & JURÁK, M. 2003. Research Laboratory of Noise and Vibration Diagnostics at the Department of Control Systems and Instrumentation. In *Active Noise and Vibration Control Methods.* Krakow (Poland) : AGH Krakow, 05/2003, p. 54 (Abstract Proceedings). Full paper 6 pp. [CD ROM Proceedings]. ISBN 83-916516-6-5.

[11] ŠKUTA, J., BABIUCH, M. & TŮMA, J. 2007. Design of hardware of inertial navigation systems. In *ENGINEERING MECHANICS 2007*. Žďár nad Sázavou, 05/2007, pp. 277. ISBN 978-80-87012-06-2.

[12] TŮMA, J., SMUTNÝ, L., KOČÍ, P. Experiences and Device of R&D Laboratory of Noise and Vibration Diagnostics at Department of Control Systems & Instrumentation VŠB-TU Ostrava. In *Principia Cybernetica 03*. Liberec : TU Liberec, 3.-5.9. 2003, s. 148-152. ISBN 80-7083-733-0.

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