Evaluation of amplitude of low frequency spectrum components using ordinary accelerometers

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Vyhodnocení nízkých kmitočtů pomocí běžného akcelerometru

The paper deals with measurement and further evaluation of amplitude of spectrum components with a frequency ranging from 0.2Hz to 1Hz for pseudo-periodical processes. For example a car engine can produce random burst shaking if power contribution to the overall engine power is differing from each other individual cylinder. The amount of burst shaking is equal to quality and settings of car engine. The suggested methodology enables us to evaluate this burst shaking using ordinary accelerometers. The PULSE analyzer and three axis accelerometer were used as instrumentation for these measurements.

***Key words**: Accelerometer, PULSE analyzer, Frequency analysis*

Introduction

The main topic of the paper deals with measurements and following signal processing of low frequency vibration ranging from 0.2Hz to 1Hz, which are belonging to pseudo periodic processes. For example, a car engine running at idle speed can excite low frequency vibration in various levels, witch are transferring to the car body and a car driver. This low frequency vibration appears to be disturbing and causes the driver suspicion that something is getting wrong. The vibration level informs about the engine tuning.

The below described method shows how it is possible to estimate components of the vibration signal with frequencies less than 1 Hz using an ordinary accelerometers. Random burst and suddenly appearing vibrations due to the non-uniformly engine running are repeated in the time interval ranging from 1 sec to 4 sec, which corresponds to the frequency from 1 Hz to 0,25 Hz. The ordinary accelerometers works in the frequency range 10 Hz through 10 kHz. As an instrumentation the BK signal analyzer an three axis accelerometers were used.

Measurement results

Experiments were performed in a lab, where the stationary car was running at the idle speed of 800 RPM. When the car engine is running uniformly the car driver is not detecting any unpleasant vibration, in spite of the fact that this random vibration is under the threshold, which is injurious health. But the engine under test excites unpleasant vibration. Fig. 1 is showing the accelerometer placement close to the engine mount damper. The signal recording was organized by double crankshaft revolutions.

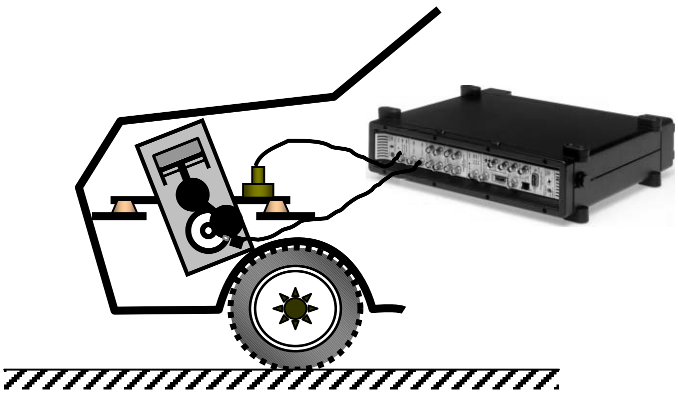

Fig. 1. Accelerometer placement and experimental setup.

The recorded time history in the signal analyzer PULSE was imported into Signal Analyzer 1.21.0, the indoor software of VSB - Technical University of Ostrava. The acceleration dominating components

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were identified using the software instrument called Autospectrum. The processing itself was focused at handing with acceleration signal segments corresponding to the double engine revolution.

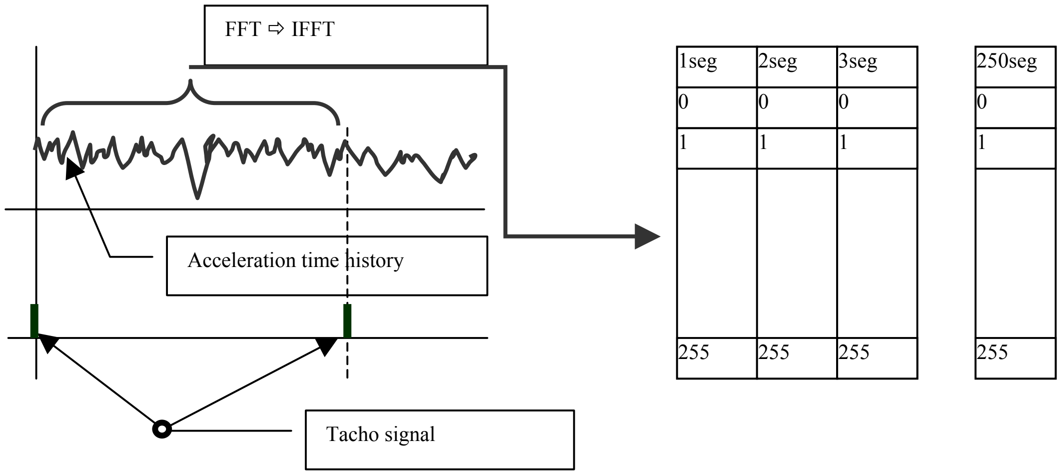

Fig. 2. Acceleration segments arrangement.

As it was mentioned the engine rotational speed was 800 RPM. The frequency of fuel ignitions is equal approximately to 26Hz. If the corresponding frequency spectrum component in the signal for x and y direction is isolated using a band pass filter then these components creates an orbit, which is shown in Fig. 3.

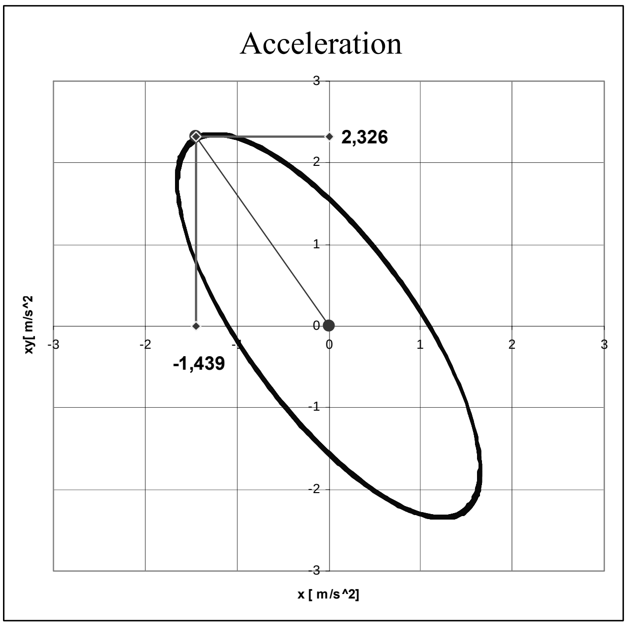

Fig. 3. Acceleration orbit plot.

As it is shown in Fig. 3 the engine mass acts forces exciting vibration in two axises. The acceleration in the X-axis is equal to a1=1,439 m/s2.while the acceleration in the Y-axis is equal to a2=2,326 m/s2 .

The force acting at the engine mass of 80 kg is as follows:
Direction of X-axis

$$F = m\,a_1 = 80 \text{ x } 1{,}439 = 115{,}12 \qquad [N]$$

Direction of X-axis

$$F = m\,a_1 = 80 \text{ x } 2{,}326 = 186{,}08 \qquad [N]$$

The engine complete revolution time interval is equal to 0,034 sec.

As the car under test is standing on the lab floor the stiffness against vibration id much lower in the longitudinal (S-axis) direction than in the vertical (Y-axis) direction. The dominating amplitude of vibration is in the longitudinal (S-axis) direction as it is shown in Fig. 4. The orbit plot in this figure shows the engine displacement during 9 sec. The reader can compare the displacement in both the direction X and Y.

Conclusion

Analysis of the operational data shows that the ordinary accelerometers with the frequency range beginning from 10 Hz can be employed for identification of vibration repeating with the frequency 0.25 Hz.

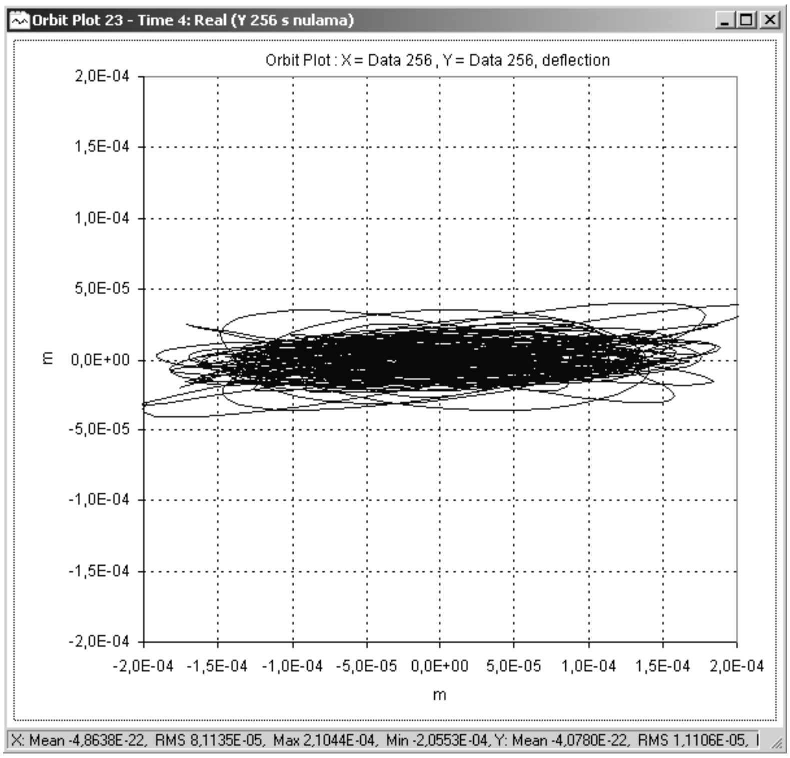

Fig. 4. Sequence of orbit plots lasting 9sec.

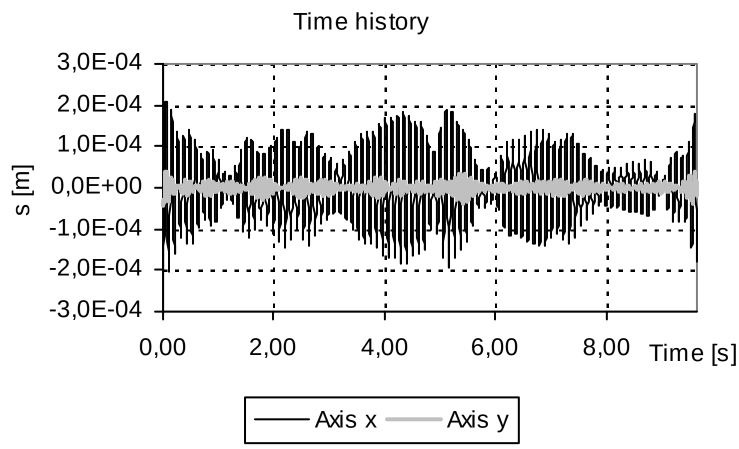

Fig. 5. Vibration time history in displacement.

Concluding remarks

Subjective feeling of ride comfort is important for today's cars. Random burst shaking while the car engine is running at idle is a phenomenon that is very disturbing for drivers. This phenomenon is a sign that is something wrong for suspicion customers. The paper deals with engine vibration measurements and consecutive assessment of engine trajectory shape. The measurement system was instrumented by PULSE, the signal analyser. Time history of vibration was spited into time interval corresponding to the engine double revolutions. The time records were improved by filtration in the frequency domain using the Fourier transform. The analysis results in planar orbit plots of the engine point where it is attached the absorber.

The suggested methodology enables us to evaluate this burst shaking using ordinary accelerometers.

References

Kočí, P, Tůma, J.: Incremental rotary encoders accuracy. In Proceedings of 7th „International Carpathian Control Conference". Ostrava: VŠB-TU Ostrava, 29. – 31. 5. 2006, *pp. 257 – 260. ISBN 80-248-1066-2*.

Kočí, P.: Vibration of Car Engine Running at Idle. In Proceedings of 6th International Carpathian Control Conference. Volume II. Miskolc-Lillafüred, Hungary : University of Miskolc, *May 24-27, 2005, pp. 207-212. ISBN 963-661-645-0.*