OPTICAL ANALYSIS OF AN IMPACT ATTENUATOR DEFORMATION

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Task specification

Goal of this work is to analyze the deformation of a impact attenuator for a Formula Student Germany racing car using two simultaneous independent measurements. First analysis will use data from accelerometers, second will use data obtained from hi-speed video using image analysis. FSG rules require experimental measurement with use of accelerometers, optical analysis will serve in this case as a verification of measured data and as a further proof of correctness of the experiment.

FSG requirements for the crashtest:

- car weight 300 kg,
- car impact speed 7 m/s,
- maximum average deceleration 20 G,
- maximum peak deceleration 40 G.

Design of the measurement chain for deformation analysis

Measurement chain for this experiment was designed in such way, that results obtained from it could be used in Impact attenuator report for FSG Hockenheim 2009. That includes restriction on measuring equipment and conditions during experiment. Crash itself was designed as a straight horizontal impact of a car with required parameters into a flat rigid surface perpendicular to the direction of impact.

Optical analysis of deformation using hi-speed camera

Data acquired from optical analysis serve as:

- verification of data from accelerometers
- accurate determining of impact speed
- accurate determining of actual deformation
- accurate determining of time duration of the impact

Using derivation of car translation obtained from optical analysis, we can determine the velocity and acceleration, comparing it to results from accelerometer measurement.

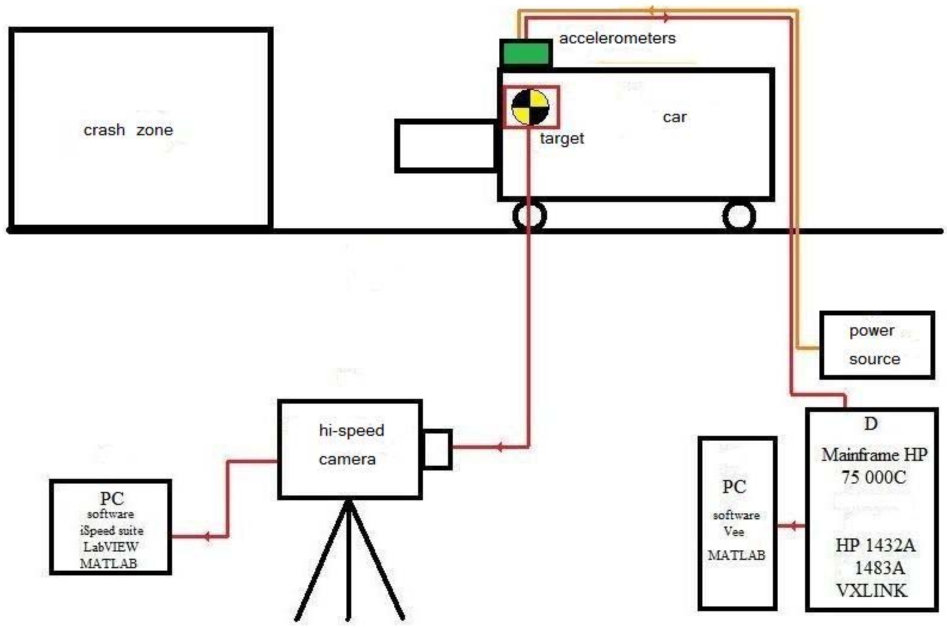

Fig. 1. *Scheme of experiment*

Necessary data for analysis:

- Position of the car related to crash zone. Crash zone and camera were both stationary, so we can assume that local coordinate system of particular frames will be also the global coordinate system of the experiment.
- Time. Video was recorded at constant frame rate of 3000 frames per second. From that we can assume, that time shift between particular frames is constant. It can be determined as inverse value of frames per second.

Determining position of the car

Image analysis was realized in LabWIEV with Vision Development Module. The image is converted to Grayscale format and the processed using Vision Assistance functions. Most important step in this process is pattern matching, during which the presence and position of a given pattern are evaluated. The pattern analyzed is circular target with cross and two quarters painted black. There are two targets for better accuracy, the right one serves as a template for both of them. Unit of the frame coordinate system is pixel. To convert it to metric units, we need to find the correlation between pixels and millimeters. For this, we use ruler painted under the targets, which has known dimensions.

- Position of the car is represented by the position of both targets
- Center of the template has offset to correlate with center of the target
- For a more robust algorithm, detection of a rotated pattern was enabled and the number of wanted patterns to be found was set to 2, so we could lower the correlation criteria.
- Algorithm can determine the positions on a sub-pixel level for better accuracy

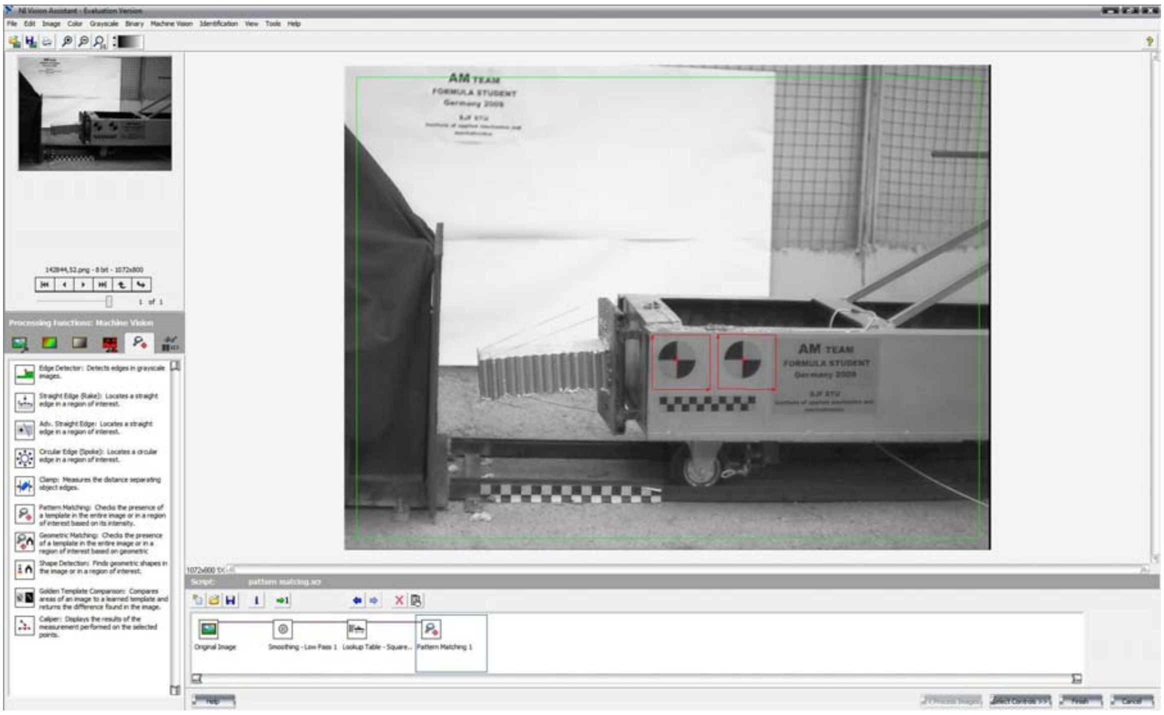

Fig. 2. Pattern matching using Vision Assistant

Processing of measured data

Statistic was used to obtain more precise position of the car. From the positions of the two targets, one representative position was calculated to represent the position of the car. After obtaining the position of the car for each frame, knowing the time interval between two subsequent frames, we could perform numerical derivation of the position in time and thus determine the velocity of the car in time. By repeating this process we could obtain acceleration of the car in time. To obtain relatively smooth and accurate course of acceleration, we made an approximation of the velocity course. This was done by using MATLAB SplineTool function.

Measurement evaluation

From measurement with accelerometers, following acceleration course was obtained.

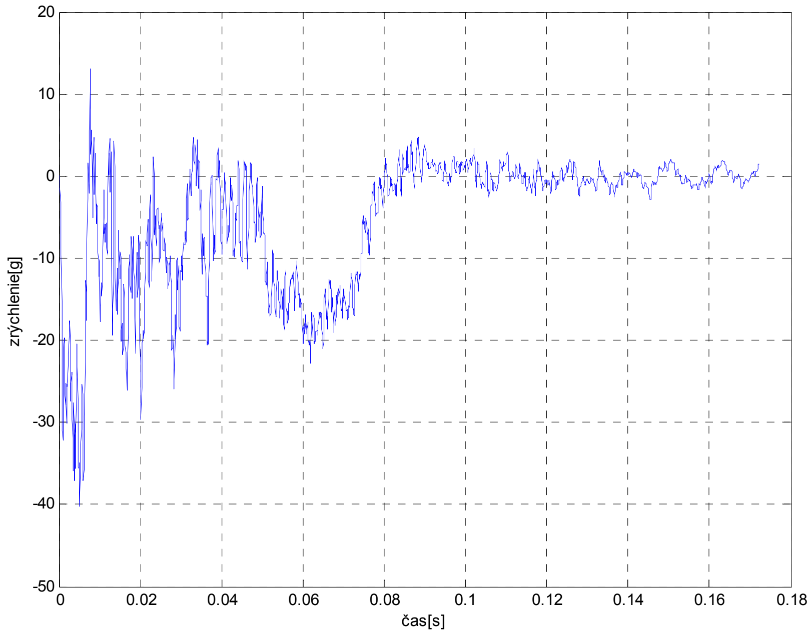

Fig. 3. *Signal from accelerometer*

Maximal reached acceleration value was 40 G, which is maximum peak value allowed by FSG. Average acceleration value was 10,8255 G
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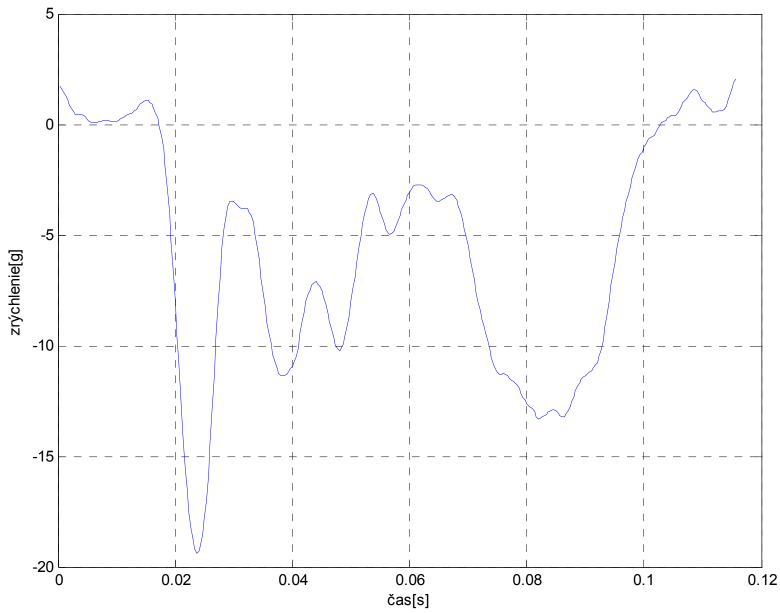

Fig. 4. *Signal from hi-speed camera*

Maximum peak value 19,37 G
Average value 7,3214 G

We can compare the two signals. They are significantly similar, but the peak values of the acceleration course obtained from optical analysis has significantly lower peaks. This can be caused mainly by two factors:

- Signal from accelerometer is not filtered;
- Signal from camera is approximated using spline curve.

Using filters on the signal from accelerometer would lower the peaks, but it is not necessary. When approximating signal with spline curve, biggest distortion is in area of peaks, lowering the peak values significantly. It also causes minor lowering of the average values. Taking all this in account, we can consider both signals similar and both measurement correct.

References:

[1] ĎURANNA, R. *Analýza deformácie crash boxu.* Bratislava: STU, 2009.