Dummy Kinematics Assessment – Evaluation of a Combined Gyro and Accelerometer Set-up

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I. INTRODUCTION

Crash test dummy kinematics is commonly obtained from high-speed video recordings or other optical methods. The present study evaluates a cost-efficient sensor system combining gyros and accelerometers to derive the kinematics of different parts of a dummy. This evaluation was done on the newly designed human surrogates, the Seat Evaluation Tools (SET) 50F and 50M [1], developed for low severity rear impacts and here equipped with gyros at four locations.

II. METHODS

The SET 50F and 50M were equipped with four sensors, each integrating gyros together with three accelerometers (TE Connectivity model 633 six-degrees of freedom (6-DOF) sensor), placed at three levels on the spine (T1, T8 and pelvis) and inside the head. The 633 6-DOF sensor is an analog sensor including outputs of three gyroscope/rate sensors and three accelerometers in one package. The gyros and accelerometers were aligned orthogonally to each other which allows the user to measure motions in all 6-DOF. This would in theory make it possible to obtain the angular displacement from the measurement and through further processing of the sensor output data, also obtain horizontal and vertical displacement. The SET 50M was run in sled tests at a delta-v of 7 km/h in a laboratory seat, corresponding to a volunteer test set-up described in [2].

The analysis of the signals from the gyros and accelerometers was done using a software especially developed by the Swedish National Road and Transport Research Institute (VTI) for this type of crash study. The software programme is intended to be made available as open source on the OpenVT platform [3]. The sampling rate was 10 kHz, and the signals were filtered using a CFC180 low pass filter before being used. The change of coordinate systems from sensor-local to a global fixed system was made using quaternion formulation to minimize numerical problems. Signal integration was made using the trapezoidal method, after comparisons with the Simpson method showed no observable difference.

III. INITIAL FINDINGS

Results obtained with the SET 50M were used as a pilot in the present work. Initial findings showed good agreement between the angular displacement obtained from the video analysis and the output from the gyros (Figure 1). Angular and spatial displacement data derived from video was available only for the head, T1 and pelvis, while sensor data also included T8. Data from four repeated collision tests were included, and Figure 1 shows the analysis of one of the collision tests, which is representative for all the four tests. Although it transpired that the data from the gyros are accurate and repeatable, the data from the accelerometers exhibited a greater variability between tests. From static measurements with one g acceleration (gravity) applied in different directions it was concluded that the accelerometers were very sensitive to temperature variations for accelerations of this order of magnitude.

Preliminary findings from comparisons of spatial displacement between video and accelerometer derived data, indicate that the temperature effect can be up to 10-20%. Further investigation of the temperature influence in these accelerometers is needed to establish whether accurate measurement of the accelerometer temperature can be used as input to compensate and remove the artifact from the temperature variations.

In contrast to using the measured rate from the gyro, which only requires a single integration, the acceleration outputs must be integrated twice to obtain the spatial displacements, making that particular measure more sensitive to sensor inaccuracies.

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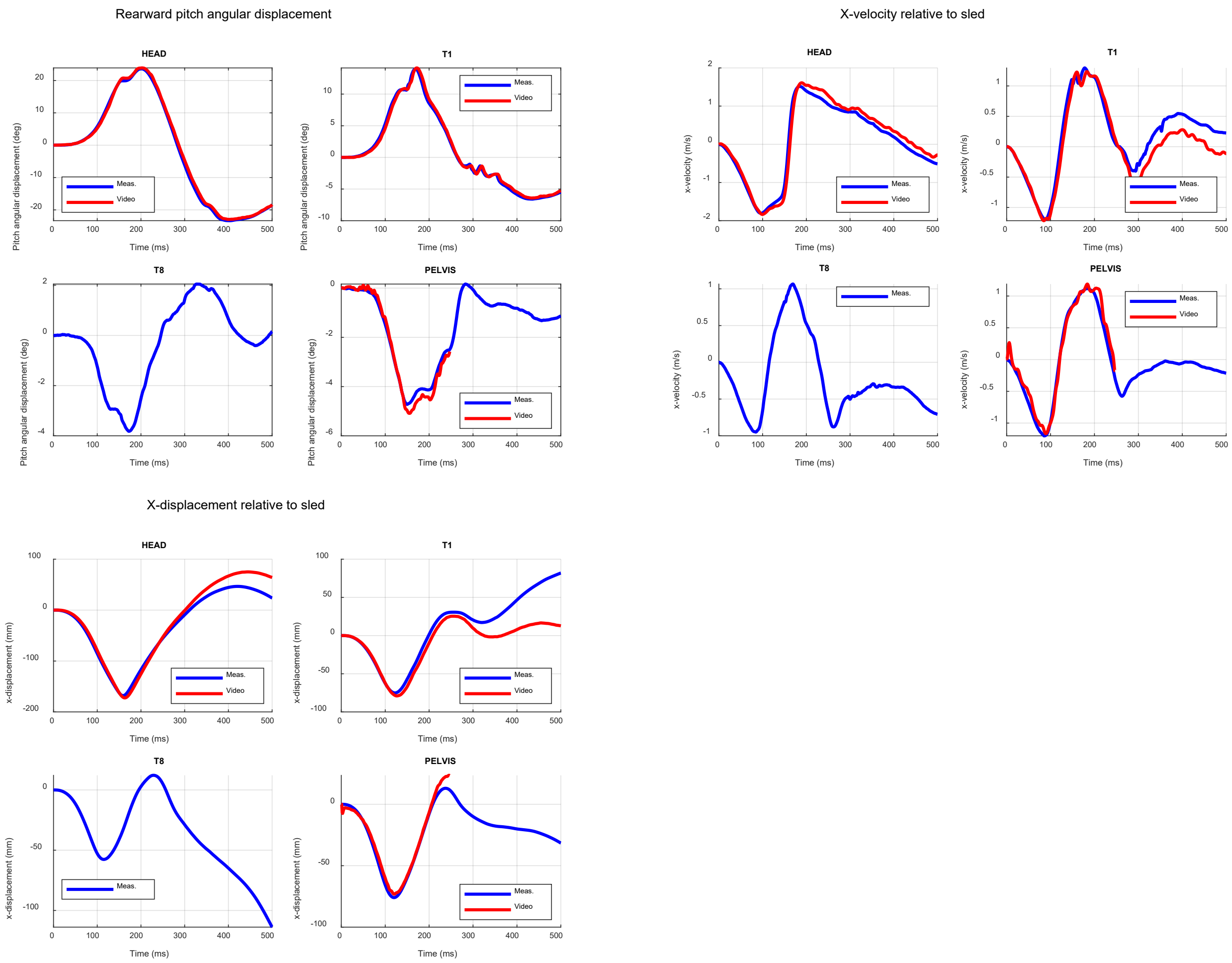

Figure 1. Video analysis data (red) compared to sensor data (blue) from rear impact sled test at delta-v 7 km/h with the SET 50M. The marker on the pelvis for the video analysis was not visible after 250 ms after impact.

IV. DISCUSSION

The analyses of the 7 km/h collisions showed promising initial results. The kinematics of human surrogates in crash tests can be obtained from the TE Connectivity model 633 combined gyro and accelerometer unit for an initial part of the motion. For the angular displacement no significant deviation was seen between the video analysis output and the sensor output for head and T1, but a small discrepancy was observed from around 150 ms for the pelvic motion. The pelvic deviation may however stem from difficulties tracking the pelvis movement from video at larger time values. For the linear displacements, a clear deviation was observed, generally starting between 150 – 250 ms after impact, depending on sensor and direction and this error tended to grow over time. However, further refinements of the software program, as well as additional evaluation testing at higher impact velocities, are needed to evaluate to what extent the dummy kinematics can be accurately obtained from the gyro and accelerometer combination, also for longer test durations. The SETs are constructed to be used in tests up to delta-v 24 km/h and further tests will be done to confirm the expectation that motion from the gyros can be obtained in the same way as been reported in this study for the whole impact range of the SETs.

V. ACKNOWLEDGEMENT

This SETs were developed in the VIRTUAL project by funding from the EU Horizon 2020 Research and Innovation Programme under Grant Agreement No. 768960. Tommy Pettersson has been in charge of the details regarding specifications of the materials and properties of the SETs.

VI. REFERENCES

[1] Karemyr et al., VTI report 1147A, 2022.
[2] Linder et al., Accident Analysis and Prevention, 2013.
[3] https://openvt.eu/set/set_signal_processing