Abridgment

Test Vehicle Kinematics by High-Speed Photography and Accelerometer Data

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Full-scale tests of vehicles influencing guardrail or median barrier systems involve complex dynamic mechanisms that are extremely difficult to characterize analytically. Thus, satisfactory theoretical values of the vehicle kinematics cannot be determined for correlating results obtained by experimental means. This abridgment concerns the results of a simple experimental test by which these theoretical quantities were established. Experimental data were collected by means of high-speed photography and accelerometers in the same manner as that used in the full-scale tests, and the results of the two techniques are compared with theoretical values.

EXPERIMENTAL PROGRAM

In the interest of maintaining a commonality of technique with the full-scale tests and the evaluation experiment, the simple two-target test apparatus shown in Figure 1 was devised. By rotating the apparatus at a constant angular speed $\dot{\theta}$, the theoretical nonzero kinematic quantities of Target 1 could be easily established by the relationships

$$x = r \cos \theta$$

$$y = r \sin \theta$$

$$v_{lat.} = r \dot{\theta}$$

$$a_{long.} = r \dot{\theta}^2$$

where r is the radius of rotation and θ is the heading angle. These quantities could then be used to evaluate the experimental values. In conducting the test, the procedures were identical to those used in the full-scale tests. For example, the initial position and velocities obtained from the high-speed film data were used as initial conditions for integration of the accelerometer data. The instantaneous heading angles required in the accelerometer data reduction were also taken from the film results.

Figure 1. Plan of test apparatus.

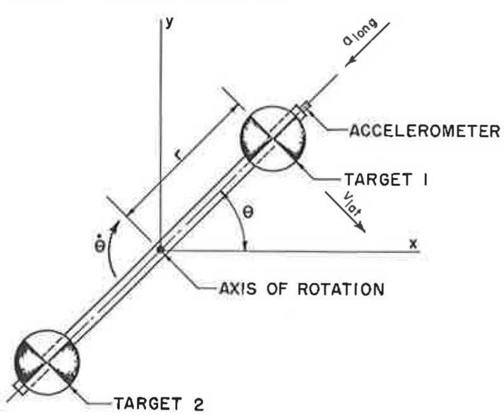


Figure 2 shows a comparison of longitudinal accelerations in which the accelerometers would be expected to give better results. Figure 3 is a comparison of x-coordinates in which the high-speed photography would be expected to be better. In the photography runs, the maximum degree of curve fit for the data points was specified at $k_{max} = 20°$, and film readings were taken at every frame. Film speeds were 196 and 168 frames per second for the two data cameras used in the experiment.

To check the sensitivity of the maximum degree of curve fit and the sampling rates with the high-speed photography, runs were made for every frame with $k_{max} = 10°$ and $k_{max} = 20°$, and for every second, fourth, and eighth frame with $k_{max} = 20°$. Figures 4 and 5 show plots of the results for longitudinal accelerations and lateral velocities, respectively. Also shown on the figures are the theoretical values and the 5 percent and 10 percent bands. Clearly indicated in both figures is the characteristic tendency for the curve-fitted quantities to blow up near the ends of the data. In these runs, data sampling was started at 0.087 second before the first location of interest and extended well past one revolution of the test apparatus. Results of the data reductions were computed at 0.01-second intervals from time t = 0 to time t = 1.00 second, the end of one revolution. This produced 101 pairs of data points for comparison purposes.

RESULTS

Figure 2, where the accelerometer data were expected to give better results, shows longitudinal acceleration values for slightly more than half a revolution of the test apparatus. Of the total of 101 pairs of data points for the full revolution, 69 of the photography points and 32 of the accelerometer points were closer to the theoretical value. Figure 3 shows that both techniques are close for the x-coordinate. Of the 101 data point pairs, the photography gave results closer to theoretical in 62 cases, accelerometer data were closer in 37 cases, and, to two decimal places, the results of the two methods were the same for two cases. From these and other figures, a preliminary conclusion can be drawn that the high-speed cine data are probably as accurate as the accelerometer data for all of the kinematic quantities. However, the cine data will not indicate the high-frequency peaks that are characteristic of accelerometer data in the full-scale tests. Much of this fluctuation is caused by vehicle ringing and is of such high frequency that it is not likely to be felt by the vehicle occupant.

As expected, Figures 4 and 5 show that the fluctuations of the results were of greater magnitude as the sampling rate was decreased. Changing the maximum

Figure 2. Comparison of longitudinal accelerations.

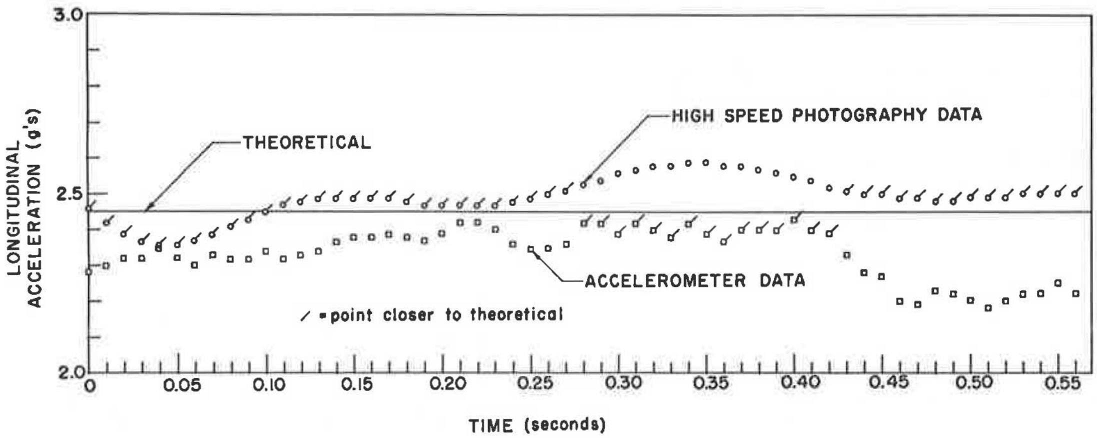


Figure 3. Comparison of x-coordinates.

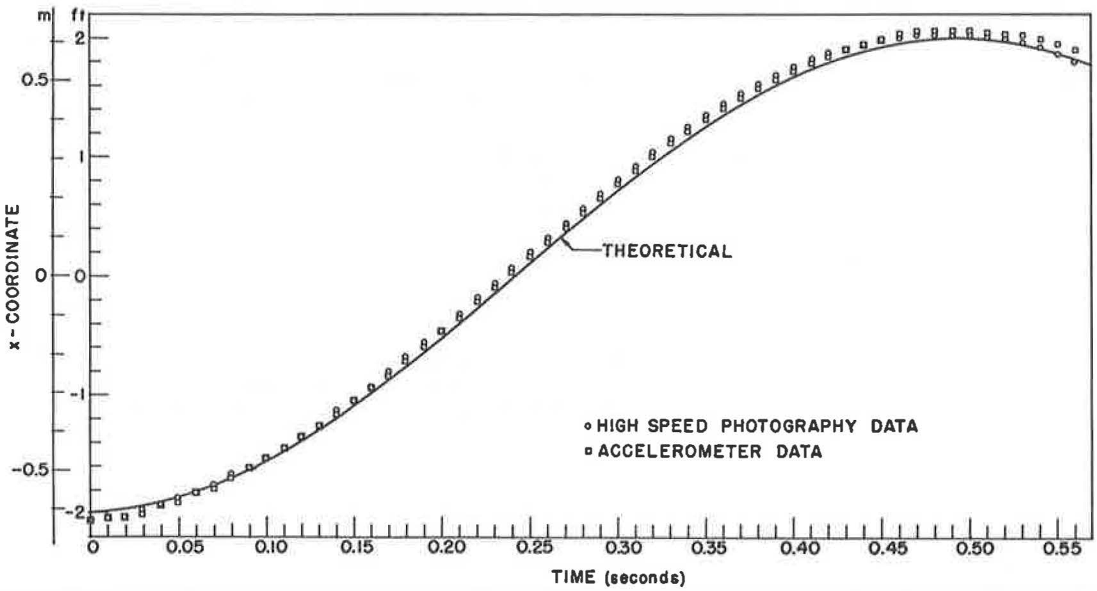


Figure 4. Longitudinal accelerations for various sampling rates.

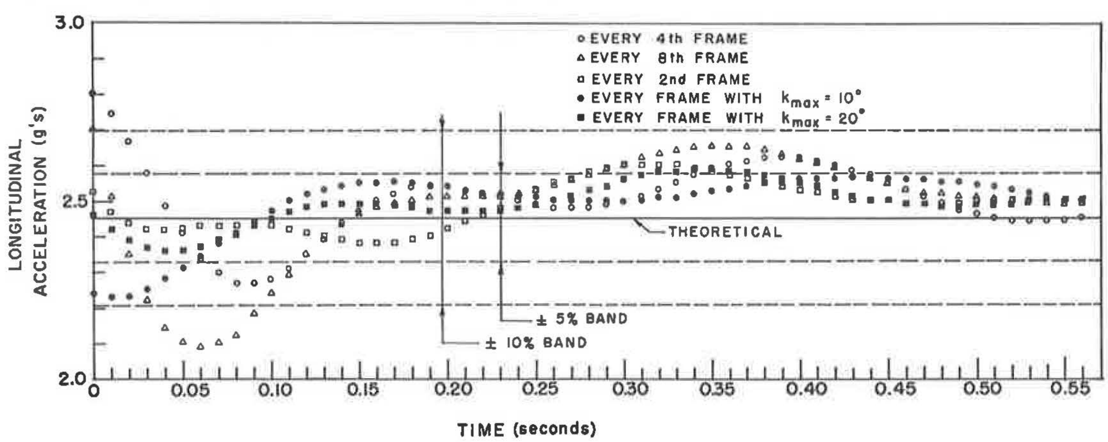
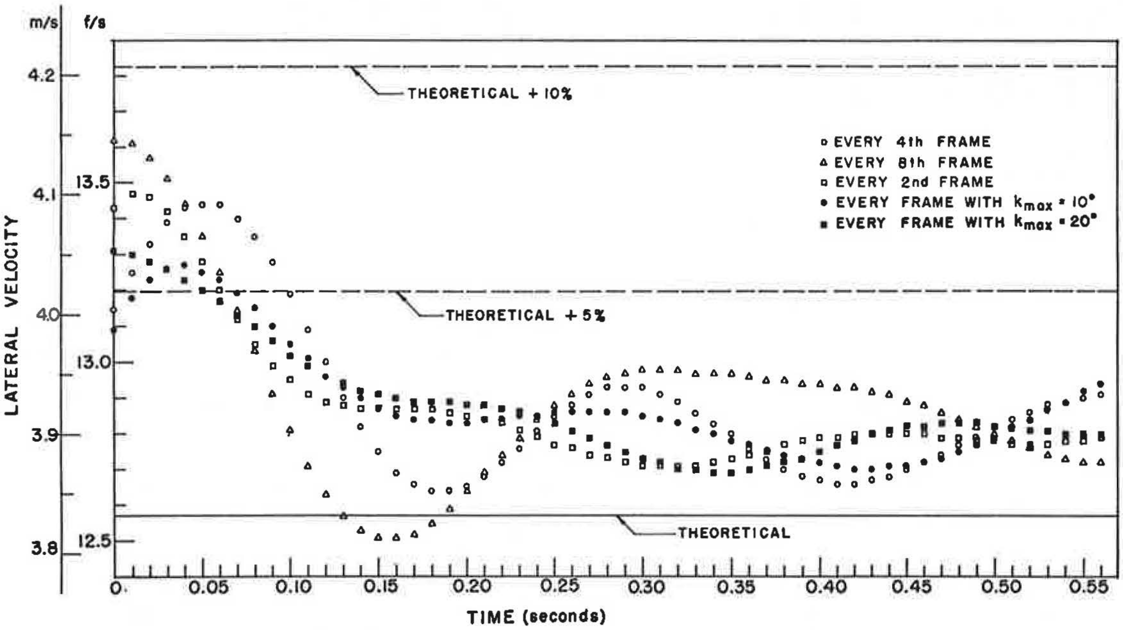


Figure 5. Lateral velocities for various sampling rates.



degree of curve from 10° to 20° did not appear to materially affect the results. To be reasonably confident of results with 5 percent accuracy, the figures indicate that at least every fourth frame should be read. With film speeds of approximately 200 frames per second in the evaluation experiment and 500 frames per second in the full-scale tests, a corresponding sampling rate for the full-scale tests would be 4 (500/200) or every tenth frame. Thus, it can be assumed that full-scale test runs with maximum 10° curve fits, data sampling at every sixth frame, and sampling that brackets the event by 0.10 second on each end will produce kinematic quantities within ±5 percent of the actual values.

CONCLUSIONS

It has been shown by means of a simple test how the data-acquisition techniques of high-speed photography and accelerometer readings compare with theoretical values. It had been assumed that the differentiation of cine data would not be as accurate as integration of accelerometer data for the desired kinematic quantities. However, this was not the case, and it can be concluded from this study that the cine data will yield results that are just as accurate as, and probably more accurate than, the accelerometer data. Of course, considerably more instrumentation is necessary for retrieval of the accelerometer data and can present undesirable sources of instrument error. Furthermore, initial conditions must be known in the integration process, and the instantaneous direction must be determined if the motion is curvilinear. The high-speed cine retrieval has the advantages of greater simplicity and the self-starting characteristic, but care must be exercised in the differentiation of the data. The errors caused by differentiation of curve fits near the ends of the sampled data can be made less significant if the period of interest can be bracketed on both ends by the data sampling.

ACKNOWLEDGMENTS

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