Reliability-Based Design Optimization of Highway Horizontal Curves Based on First-Order Reliability Method

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ABSTRACT

The main purpose of this study is to determine minimum radius of highway horizontal curves considering randomness of input variables and parameters. Although American Association of State Highway and Transportation Officials (AASHTO) Green Book provides a method to calculate a minimum radius of horizontal curve at given speed and superelevation, since the method primarily focuses on the risk of sideslip and only consider a deterministic model, it is unsatisfactory to deal with the rollover accident and the influences of uncertain circumstances such as vehicle speed, steer angle, road surface condition, and superelevation. To overcome the disadvantages of the method recommended by AASHTO, this study takes into account the failure modes of rollover as well as sideslip in formulating analytic models.

In order to accurately describe safety failure modes of a ground vehicle, the analytic models are derived considering nonlinear characteristics of vehicle behavior caused by suspensions and tires. Existing studies have ignored the effect of nonlinear properties on vehicle's handling behavior and this has caused discrepancy between a mathematical model and actual vehicle dynamics. Instead of considering all of the nonlinear properties for the accuracy of analytic model, in this study, an alternative approach is developed using the values collected from commercial software, Trucksim, which has high fidelity in vehicle dynamics.

The reliability analysis is performed using the First-Order Reliability Method (FORM). Furthermore, a sensitivity analysis investigating the influences of each random variable on vehicle sideslip and rollover is carried out. The results of the reliability analysis show that the current method recommended by AASHTO focuses on only sideslip accident on dry road and it corresponds well with existing researches.

Based on the inverse reliability analysis (IRA) method, RBDO is conducted to find optimum radius that satisfies the target probability of failure to secure the safety of a vehicle on curves which is the main objective of this study. The objective function is to minimize the radius of curves at given superelevation, road friction condition, and design speed. Compared with the disadvantage of the current design method that mainly concerns about sideslip and dry road condition, this study is expected to propose a new methodology to design the minimum radius of horizontal curves which can extend its scope to comprehensive design method to cover all major aspects of hazard such as rollover accident and severe road condition.

REFERENCES

- Tu, J., and Choi, K. K., "A New Study on Reliability-Based Design Optimization," Journal of Mechanical Design, Vol. 121, No. 4, pp. 557–564, 1999.
- You, K., Sun, L., and Gu, W., "Reliability-Based Risk Analysis of Roadway Horizontal Curves", Journal of Transportation Engineering, Vol. 138, No. 8, pp. 1071–1081, 2012
- Chen, F., and Chen, S., "Reliability-Based Assessment of Vehicle Safety in Adverse Driving Conditions", Transportation Research Part C: Emerging Technologies, Vol. 19, No. 1, pp. 156-168, 2012