Multi-Body Dynamics Modeling for Normal Road Transport of Spent Nuclear Fuel

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1. Introduction

Spent fuel which is generated after the fission process in nuclear power plant must be safely handled due to its risks and importance. In these circumstances, for evaluating the structural integrity of the spent nuclear fuel, the normal road transport test was conducted in 2020 by using a commercial trailer with the KORAD-21 transport cask and dummy spent nuclear fuel [1]. In this research, in order to analytically simulate the vibration and impact at the spent nuclear fuel that occurs during the normal transport conditions, a multi-body dynamics (MBD) model was developed. For obtaining the MBD model, two kinds of transport scenarios (pass over bump and avoid obstacle) were considered. The usefulness of the MBD model was verified through the comparison with the test results for pass over bump and obstacle avoidance test.

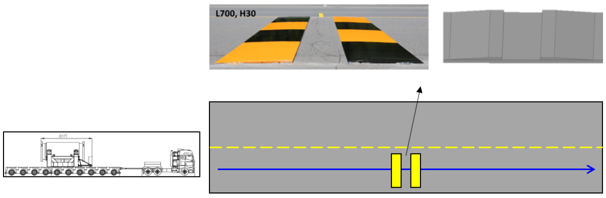
2. Normal Road Transport Test

In 2020, the normal road transport test was performed as shown in Figure 1 within Doosan Heavy Industries & Construction site [1].

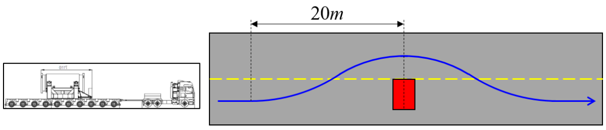
Figure 1 Normal road transport test

In the normal road transport test, two driving scenarios were considered as follows:

(a) Pass over bump: The trailer starts with a speed 5km/h on flat ground. The scenario ends after running over the bump as shown in Figure 2a.
(b) Obstacle avoidance: The trailer starts with a speed 30km/h on flat ground. Assuming that the obstacle is found 20 [m] before, and it starts an evasive maneuver and returns to the original lane.



(a) Pass over bump



(b) Obstacle avoidance

Figure 2 Driving scenario

In order to obtain the vibration and impact features at the spent nuclear fuel, two kinds of sensors including strain gauge and accelerometer were attached along the vibration transmission path as shown in Figure 3.

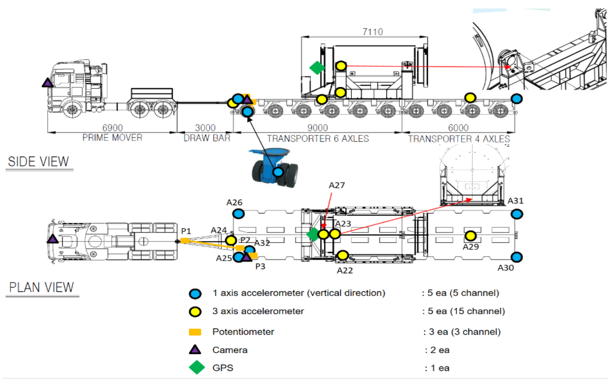


Figure 3 Sensor location on trailer and test model

3. Multi-Body Dynamics Modeling

In order to develop the 10-axle MBD trailer model for the normal road transport test, THP/SL6 and THP/SL4 from Goldhofer were applied and combined as shown in Figure 4.

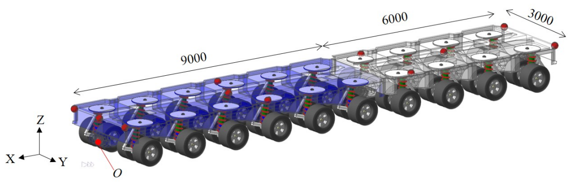


Figure 4 10-axles MBD trailer model

In this MBD trailer model, there are a total of 20 suspension systems (10-axle X 2 set). Based on the Reference [2], each suspension system was modeled.

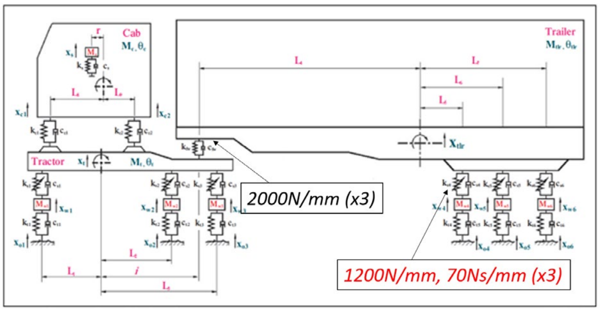


Figure 5 Schematic description for trailer suspension system [2]

In the MBD model, for analytical efficiency and simplicity, the test model (KORAD-21 transport cask and its cradle) was modeled by 2-dof MCK model as shown in Figure 6.

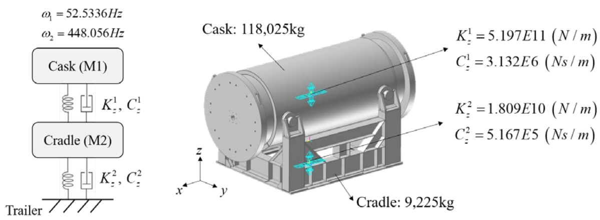


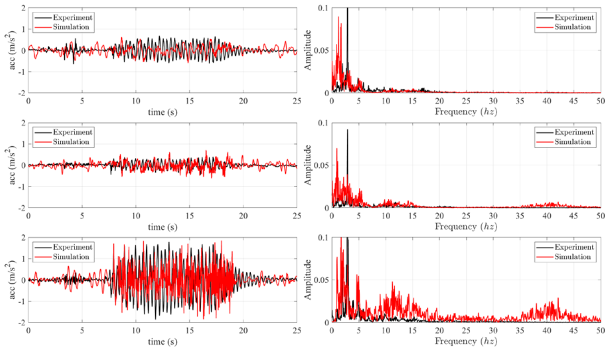
Figure 6 Schematic description for simplified 2-dof MCK test model

3. Results

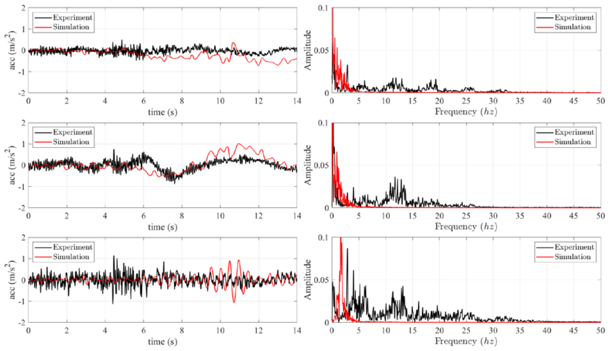
Figure 7 shows the x, y, and z-axis acceleration and frequency responses at the test model with respect to time. The tendencies of the MBD results are similar with the test in the case of pass over bump and obstacle avoidance. However, as a result of calculating the RMS error, about 30% was derived as shown in Table 1. Because the RMS error has too large value and it cannot be ignored, the MBD model have to be modified. Therefore, in a near future, our team intend to improve accuracy of the MBD model to better simulate the test results.

Table 1 RMS error

RMS error (%)	Pass over bump	Obstacle avoidance
x-axis	28.88	32.26
y-axis	20.71	28.17
z-axis	69.90	29.98



(a) Pass over bump



(b) Obstacle avoidance

Figure 7 Test and MBD model result

4. Conclusions

In this research, the multi-body dynamics (MBD) trailer model was developed based on Goldhofer's THP/SL6 and THP/SL4 trailer models by comparing with the normal road transport test results of two driving scenarios (Bump and Obstacle avoidance).

ACKNOWLEDGEMENTS

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REFERENCES

[1] Lim, J. H., Yang, Y. Y., Jeong, G. E., Lim, J. M., Cho, S. S., and Choi, W. S., "Scenarios and Instruments Locations for Heavy Trailer Empty Weight Test to Calibrate Multi-body Dynamics Modeling," Korea Radioactive Waste Society Spring Conference, 2020.

[2] M. A. Abdelkareem, M. M. Makrahy, A. M. Abd-El-Tawwab, A. EL-Razaz, M. Kamal Ahmed Ali, M. Moheyeldein, "An analytical study of the performance indices of articulated truck semi-trailer during three different cases to improve the driver comfort", Proceedings of the Institution of Mechanical Engineers, Part K: Journal of Multi-body Dynamics, 2018.