Development of a Speed Sensitive Collapsible Mechanical Speed Bump

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Abstract
A speed bump is a traffic calming device that uses vertical deflection to slow vehicles, typically used in populated area. Typical solid speed bumps made of concrete or rubber can damage vehicles' suspension components and cause discomfort to passengers even when a vehicle passes at low speed. A speed sensitive collapsible mechanical speed bump presented in this paper aims to alleviate those problems in small roads. The speed bump was shaped as a regular speed bump but with internal mechanism that allows it to collapse to a flat surface when a vehicle passes at low speed while lock-up at high speed. The trigger speed is designed at 8 km/hr. Pendulum type mechanism was used for both speed sensing and locking. Result from road test confirmed that the idea has potential for further development.

Keywords: speed bump; traffic calming device; mechanical speed sensor; mechanical design

1. Introduction

A speed bump is a traffic calming device that uses vertical deflection to slow vehicles, typically used in small local roads in populated area. Depending on its cross-sectional profile, vertical acceleration from a certain speed bump can damage vehicles' suspension components and cause discomfort or, in some occasions, injury to passengers [1] even when a vehicle passes at low speed. Yomchinda [2] explored such effects numerically. Hence, most drivers have to stop their vehicles and slowly climb over a speed bump, which is a waste of energy.

In Thailand, there is a standard on construction of speed bumps and speed humps (larger type for 50 km/hr speed) [3]. The standard, however, focused on speed humps. On speed bumps, it only mentioned length (300 – 900 mm), height (up to 75 mm) and target speed (8 km/hr in small road) but did not recommend the suitable cross-sectional profiles, which is the crucial feature of speed bumps.

The idea of using speed sensitive collapsible speed bumps is popular among inventors. Many ideas have been patented, such as [4] – [10] but very few reached the road tests. There are many problems that prevent collapsible speed bumps from being practical, including structural durability, maintenance and installation issues (which may require digging up the road). Recently there is a promising technology: one is the use of flexible shell filled with non-Newtonian fluid that react differently to speed of impact [11] but durability of the shell is still needed to be much improved.

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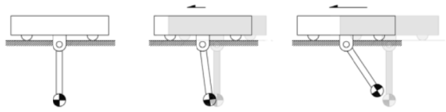
A speed sensitive collapsible mechanical speed bump developed in this work aimed to provide a robust mechanism that is durable, easy to maintain and does not require major modification of the road surface

2. Design

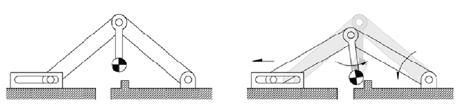
Response of the mechanism to speed of a vehicle is based on inertia of a pendulum as demonstrated in Fig. 1. When the block is accelerated to the left, due to its inertia, the pendulum cannot catch-up with the block. Hence, in relative to the block, the pendulum moves to the right. Low acceleration of the block cause small relative movement of the pendulum as shown in Fig. 1(b), and high acceleration causes large relative motion as shown in Fig. 1(c).



(a) (b) (c)

Fig. 1. Motion of a pendulum system. System at rest (a), under low acceleration (b), and under high acceleration (c).

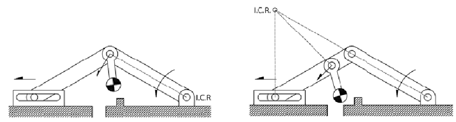
Apply the idea of inertia to a link-and-slot mechanism in Fig. 2, one can predict that the pendulum will move to the right in relative to the right most link when the link is under swift counter clockwise rotation (as a result of getting hit by a fast car running right to left).



(a) (b)

Fig. 2. Conceptual design of a speed bump System at rest (a) and system under acceleration (b).

In Fig. 3 (b), one can observe that if the pendulum is attached to the left link instead, the response will be more promptly as the instantaneous center of rotation moves away from the link.



(a) (b)

Fig. 3. Locations of I.C.R.'s when the pendulum is attached to the top pivot (a) and when it is attached to the left link (b).

The final conceptual design in Fig. 3(b) receive fine tuning in Fig. 4, by applying gear meshing to eliminate the top corner. The pendulum was shaped to mesh with the guide rail, which eliminate the need to dig the road surface. A return spring is installed to keep the mechanism in the up position

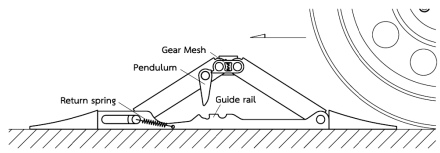


Fig. 4. Final conceptual design of the mechanical speed bump.

When a vehicle passes the speed bump at speed lower than 8 km/hr, as shown in Fig. 5, the pendulum will catch-up with other mechanism and slide along the guide rail and fold flat. This put the speed bump in a collapse mode. If the speed exceeds 8 km/hr, inertia of the pendulum will cause it to lag behind, hence it fall into the locking groove of the guide rail and lock the speed bump in the bump position as shown in Fig. 6.

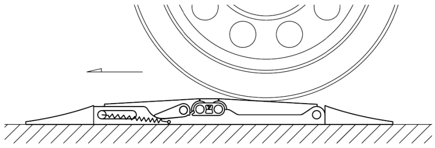


Fig. 5. Low speed pass – collapsed.

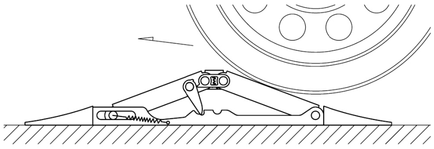


Fig. 6. High speed pass – locked-up.

The conceptual design is expanded into preliminary component design in Fig. 7. When in use there will be an array of the mechanisms in Fig. 7 lays across the lane and they will be connected together with top panels.

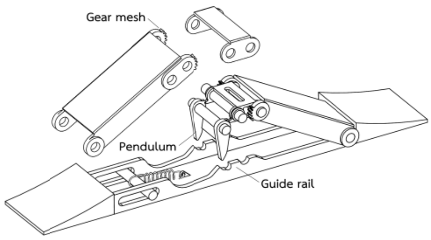


Fig. 7. Partial explode view of the conceptual design of the mechanical speed bump.

Fig. 8 shows two speed bump mechanisms connected with top panels to form a detail design for one wheel test. The major components were designed based on medium carbon steel plates, 4 mm and 8 mm thick. All pins were M12 SAE grade 8.8 steel bolts. The overall width is 400 mm, which is sufficient for one wheel testing. Overall length is 700 mm (including entrance and exit ramps, not shown). The heights are 90 mm at rest, 75 mm locked-up and 30 mm collapsed.

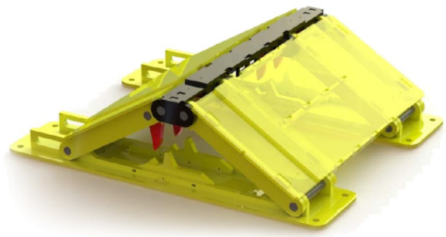


Fig. 8. Computer render of a prototype speed sensitive collapsible mechanical speed bump.

3. Computational Analysis

The design was evaluated computationally for motion, stress and deformation. In motion analysis, the suitable center of gravity and mass of the pendulum is confirmed for 8 km/hr response. Stress and deformation is analyzed by applying a uniformly distributed load of 50,000N (ten times of static load) on the top panel ramp-up side to simulate impact force under locking position. Material is medium carbon steel. The maximum stress of 216 MPa and maximum deformation of 1 mm. were found in the middle of the plate. These results confirmed that the design had sufficient strength for road test.

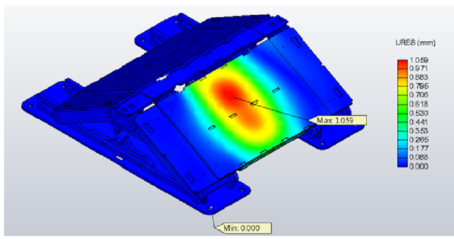


Fig. 9. Finite element analysis for deformation of the speed bump under 50,000N load.

4. Prototype

The finished prototype shown in Fig. 10 was fabricated from steel plates. The laser cut pattern along with additional machined parts are shown in Fig. 11. The prototype was then secured to the road with 4xM8 bolts, ready for the road test.

Fig. 10. Road test prototype.

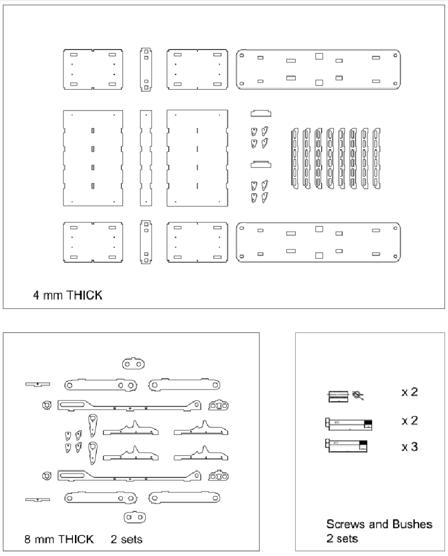


Fig. 11. Laser cut pattern and machined part.

5. Road Test

The test was set up according to Fig. 12. The purpose of the test was to verify response of the mechanism to vehicle speed. Three vehicles of different sizes were used in the test:

2012 Suzuki Swift (975kg),
2000 Chevrolet Zafira (1560kg),
2015 Ford Ranger (1963kg).

Ten test runs were conducted at different speeds. The result is shown in Table 1.

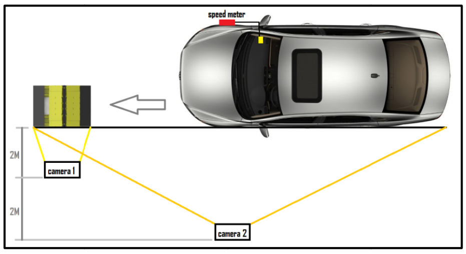


Fig. 12 Road test set up.

Fig.13 Road test.

Table.1 Road test result

#	Speed (km/hr)	Response	Vehicles
1	< 8	✓Fold	Suzuki Swift
2	> 8	× Fold	
3	8	✓ Fold	Chev. Zafira
4	18	× Fold	
5	< 8	✓ Fold	Chev. Zafira
6	15-18	✓ Lock	
7	7	✓ Fold	Chev. Zafira
8	12	✓ Lock	
9	< 8	✓ Fold	Ford Ranger
10	> 8	✓ Lock	

6. Discussion

From Table 1, 80% accuracy is observed. The information is, however, insufficient to make conclusion. The reason to have the test cut short is due to the major problems found during the test.

First, there are two pendulums and four rails used in the prototype. They did not work in perfect synchronize, which caused the top panel to twist in some tests. Second, there is a "singular point" (Fig. 14) when the tip of a pendulum hit the tip of a rail, which caused damage.

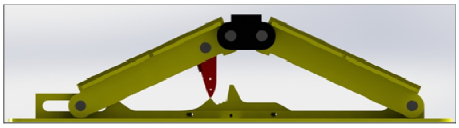


Fig. 14 Singular point.

There was also a friction problem in the axle of the pendulums that caused inconsistency. The last problem observed was bending of the rails, since the road surface underneath the prototype was uneven, which was not accounted for in the computational analysis.

7. Conclusion

This paper presented the initial phase in development of a speed sensitive collapsible mechanical speed bump. In this effort, a principle of inertia was used for speed sensing. The design aimed for simplicity and ease of installation. A preliminary road test was conducted and the result showed that the prototype has good potential. However, major problems were addressed which will be solved in the next prototype. In the future phase, the design will be revised to achieve both strength and accuracy. An in-depth investigation to vertical acceleration will also be conducted in order to determine the suitable profile under the locked-up condition.

Acknowledgements

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