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A ROAD TEST STUDY ON SPEED SENSITIVE COLLAPSIBLE MECHANICAL SPEED BUMP

Pornprom Pahubutra [a], and Dulyachot Cholaseuk [a*]

[a] *Department of Mechanical Enginering, Thammasat School of Engineering, Thammasat University Pathumtani, 12120, THAILAND.*

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ABSTRACT

A speed sensitive collapsible mechanical speed bump is a structure of a triangular shaped profile with joints that allow the bump to fold flat. The operation of the bump relies on an all mechanical system that uses a pendulum as a speed sensor. The amount of angular motion of the pendulum varies with the speed of the vehicle passing. This determines the position of the tip of the pendulum that contacts the guide rail, which can control the pendulum to fold or to lock. The speed bump is designed to lock when a vehicle passes at speed above 8 km/hr and to fold flat at the speed below 8 km/hr. This road test version was vastly improved from the conceptual prototype. The pendulum speed sensing mechanism was separated from the locking mechanism to ensure speed sensing accuracy while improving strength in the locking position. Overall profile was scaled down to fit Thailand's speed bump standard. Testing was conducted with six vehicles of different segments: an eco car, two compact sedans, two mid-size suv's and a pick-up truck. The test results show that the bump response well with the transition range of 7 – 12 km/hr.

1. INTRODUCTION

Speed bumps are widely used for speed control in highly populated area. Bumps on the road cause vehicles to slow down to avoid vertical impact, which help reducing chances of accident. According to Thailand's standard on speed bumps [1], speed bumps are usually used for entrances to car parking areas or on private roads. The length is 30 to 90 cm long and they aim to reduce the vehicle speed to 8 km/hr or lower.

Improperly designed speed bumps could be harmful to vehicles and the passengers, even though, the vehicles passing at low speed [2, 10]. Hence, researchers try to design a suitable profile that could reduce vertical impact [3]. However, this still cause discomfort to passenger. The better solution is to have a speed bump collasped if the vehicle travel below the speed limit and activated as a bump to warn or punish high speed vehicles.

*Corresponding author (D.Cholaseuk) Tel: +66-25643009 Ext 3149 Email: cdulyach@engr.tu.ac.th

Many ideas have been patented on collapsible speed bumps, such as [4] – [9], 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 to be proven.

The authors have developed a mechanical collapsible speed bump using a pendulum as a speed sensing mechanism and also as a locking mechanism [12]. It was easy to install. The bump is tuned to response well to the targeted speed of 8 km/hr. However, the pendulum design is prone to vibration. Its dimensions are too large and due to the design, it could not withstand impact load from large vehicles. The mentioned problems were fixed in this new version. The speed sensing mechanism was separated from the locking mechanism to ensure speed sensing accuracy while improving strength in the locking position. Overall profile was scaled down to fit Thailand's speed bump standard.

2. DESIGN

In development of a speed sensitive collapsible speed bump version V, the principle of inertia was still used in the pendulum sensing mechanism. When the vehicle travels fast the pendulum sensing mechanism will rotate backward in relative to the ramp which makes it falls in to a locking point in the guide rail. When the vehicle travels slow the pendulum sensing mechanism will have less rotation in relative to the ramp which makes it slides along the guide rail and allows the bump to collapse. In the previous version, the pendulum speed sensing mechanism were use as both a sensor and a locking mechanism, which lower its accuracy.

In this version, the pendulum speed sensing mechanism were separated from locking mechanism. The movement of the pendulum sensing mechanism along the guide rail will activate to the locking mechanism. When installed at 30 mm below the road surface, as shown in Figure 1, the highest point of the bump is 75 mm, which is conformed to Thailand's standard for speed humps. During locking position the height will be 60 mm. And during the fold position it will be flat. If installed on the road without digging, it will be 30 mm higher in each position. This research uses on-road installation as shown in Figure 2.

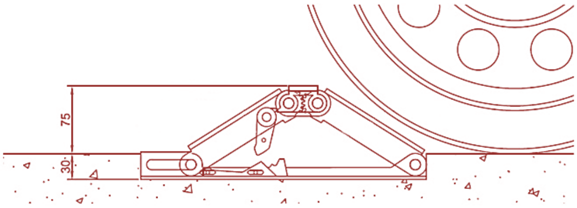

Figure 1: Installed by digging-up the road.

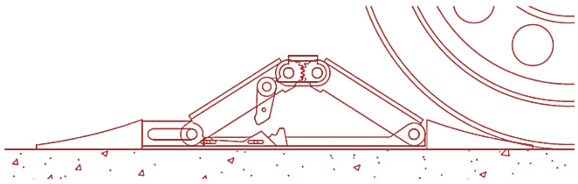
Figure 2: Installed on the road.

By kinematic analysis, Figure 3 shows that the angular velocity of speed bump decrease when the tire size become bigger. For 600 mm. tire size at the vehicle speed of 8 km/hr, the angular velocity of speed bump shall be 17 rad/s, which is used as the design condition. With the relationship in Figure 3, it is expected that the vehicle with large tire could pass the speed bump at higher speed.

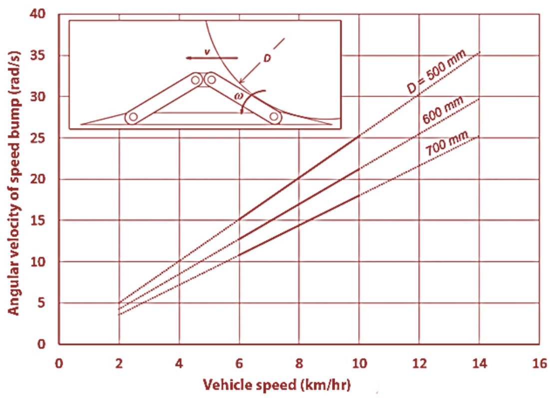

Figure 3: Relation between angular velocity of speed bump and vehicle speed.

Detail design was created on Solidworks program. This design is the fifth version. We separated the sensing mechanism from the locking mechanism to ensure sensing accuracy while improving strength in the locking position as shown on Figure 4. And Figure 5. The sensing mechanism is a pendulum which can move independent of the locking mechanism. Stress analysis was conducted on the model and it was found that the safety factor of 5 was achieved under 2-ton load.

The detail of speed bump are shown in Figure 6, which consists of (1) floor plate with locking rails, (2) approaching ramp, (3) departing ramp, (4) top plate, (5) connectors, (6) connector for sensor parts, (7) locking mechanisms, (8) lead locking mechanism, (9) pendulum speed sensing mechanism, (10) guide rail, (12) connecting pins, (12) lower connecting pin, (13) locking pivot pin and (14) rubber slope blocks. A return spring (not shown) is required to hold speedbump in the original position. For the real application of the road, a full-lane speed bump will be assembled from two sets of small bumps as shown in Figure 7.

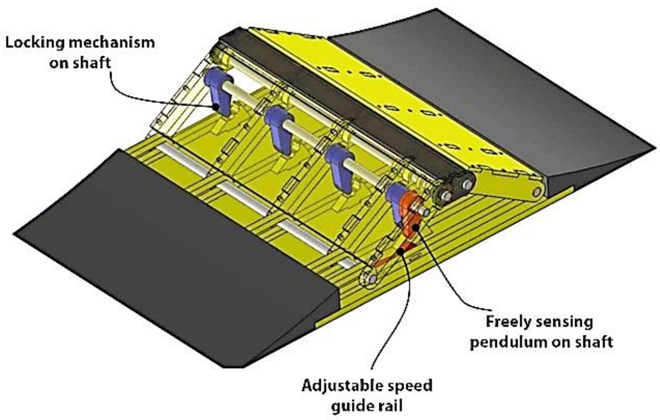

Figure 4:. Design of speed bump version V.

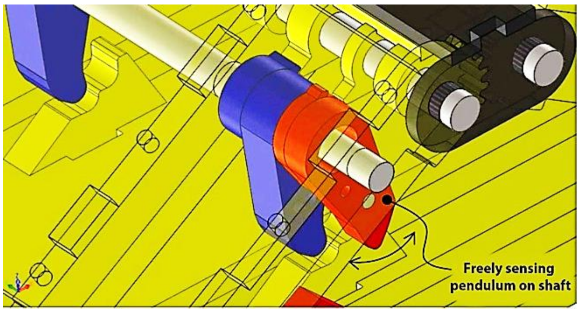

Figure 5: Zoom in to the sensing mechanism separated from locking mechanism.

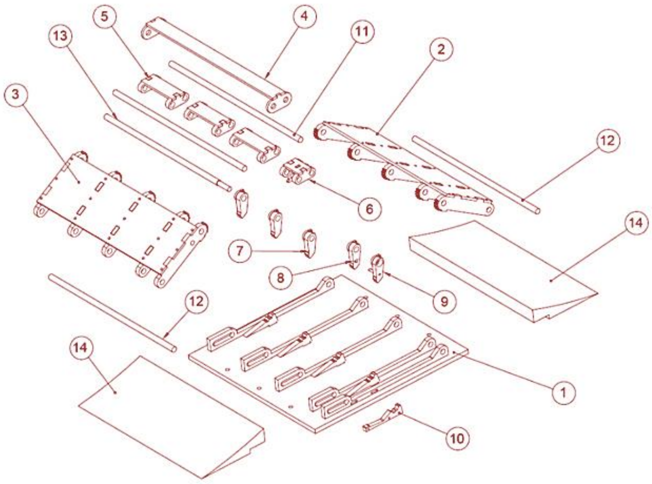

Figure 6. The detail of speed bump.

Figure 7. Full-lane speed bump.

Three working positions of the speed bump are shown in Figure 8: The initial position (a), locking position when a vehicle passing at the speed more than 8 km/hr (b) and fold-flat position when a vehicle passing at the speed lower than 8 km/hr (c).

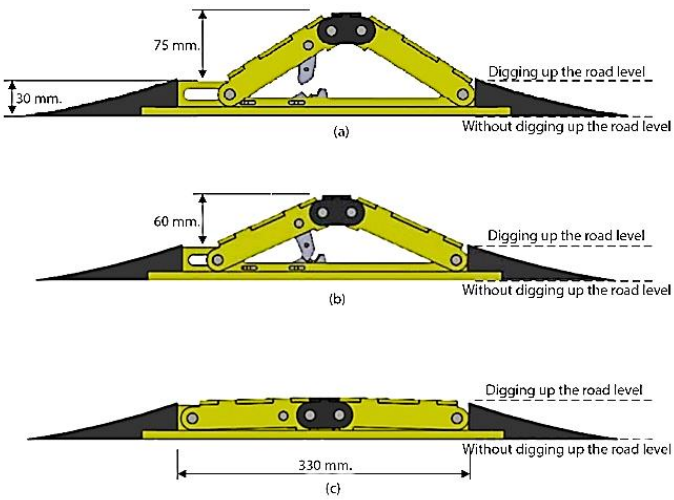

Figure 8: Speed bump position. (a) Initial position, (b) locking position, (c) fold-flat position.

3. PROTOTYPE

The major components were made of medium carbon steel plates, 5 mm and 10 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). The heights are 90 mm at rest, 75 mm at locked-position and 30 mm at flat. Internal parts are shown in Figure 9. The finished speed bump, ready for testing, is showed in Figure 10.

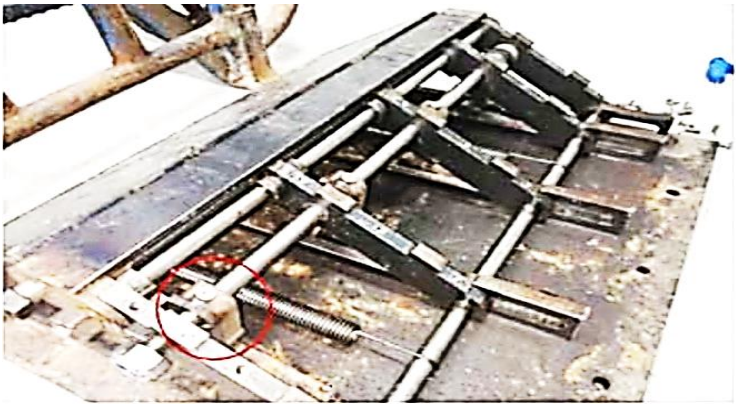

Figure 9: Locking mechanism fixed to a pivot pin.

Figure 10: A prototype speed sensitive collapsible mechanical speed bump version V.

4. ROAD TEST

The test was set up according to Figure 11. The purpose of the test was to verify the response of the mechanism to vehicle speed. Six vehicles were used in this test, as detailed in Table 1. Each vehicle were driven at different speeds (6, 7, 8, 9, 10, 12 and 14 km/hr) over the speed bump, with three repeated runs for each speed. The responses for both front and rear wheels were recorded by video cameras. Thus for each vehicle at each speed, there were 6 samples (2 wheels, front and rear x 3 repeats) and for Every vehicle at each speed, there were 36 samples (6 vehicles x 2 wheels, front and rear x 3 repeats). Figure 12 shows the initial position of the bump. When the vehicle travel over the speed bump at low speed, fold-flat position in Figure 13 is expected. Locking position in Figure 14 is expected for speed over 8 km/hr.

Table 1: Vehicles used in the test.

Vehicle model	Type	Wheel Dia. (mm)	Mass (kg)	Tire Pressure (psi)
Suzuki Swift 2012	Eco Car	600	1,035	32/30
Toyota Vios 2013	Compact	600	1,475	32/30
Mazda 3 (4D) 2016	Compact	680	1,321	32/30
Mazda CX-5 2015	SUV	680	1,600	35/35
Honda CR-V 2004	SUV	680	1,560	30/30
Isuzu D-Max 2005	Pick-up	680	1,800	38/35

Figure 11: Road test set-up.

Figure 12. Speed bump at initial position.

Figure 13: Fold- flat at 6 km/hr.

Figure 14. Locking at 12 km/hr.

The test results were compiled into locking rates. For each vehicle at each speed, the locking rate was computed as a percentage ratio of the number of samples that cause the bump to lock to the total number of samples (6 samples). Figure 15 shows the relationship between locking rate and vehicle speed. Each points correspond to result from an individual vehicle. Locking is observed from 7-12 km/hr.

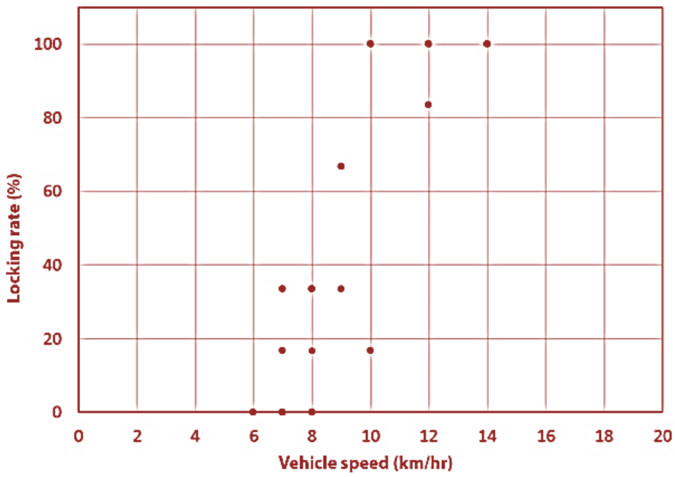

Figure 15: Locking rate vs vehicle speed passing the device.

5. DISCUSSION

The test results show different locking rates for different vehicles at the same speed, due to variations of vehicle wheel diameters and tire pressures. Upon averaging the responses for all vehicles at each speeds (36 samples for each speed), the response curve of the speed bump can be drawn as Figure 16. The response curve shows transition zone between 7 to 12 km/hr. During the test, some deformations of the floor plate were observed, due to incomplete welding. But it did not significantly affect the response of the bump. When the pendulum speed sensing mechanism slide along the guide rail during the fold-flat phase, friction leads to increasing reaction force at the pin joint. This can be fixed by adding a roller to the tip of the pendulum.

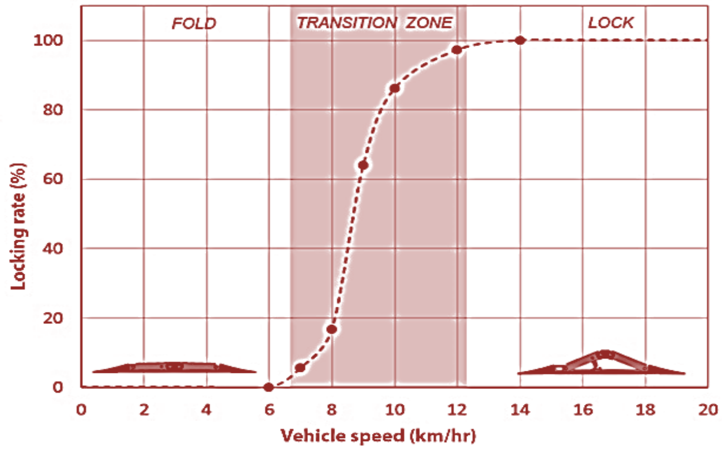

Figure 16: Response curve of the speed bump.

6. CONCLUSION

The fifth version of a speed sensitive collapsible mechanical speed bump was developed. This road test version was vastly improved from the conceptual prototype. The pendulum speed sensing mechanism was separated from the locking mechanism to ensure speed sensing accuracy while improving strength in the locking position. Overall profile was scaled down to fit Thailand's speed bump standard. Testing was conducted with six vehicles of different segments: an eco-car, two compact sedans, two mid-size suv's and a pick-up truck. The test results show that the bump response well with the transition range of 7 – 12 km/hr. Major problems were addressed which will be solved in the next prototype. Design of the sensing mechanism will be revised with a roller attached to the tip to eliminate friction between the rail and the tip of the pendulum.

7. ACKNOWLEDGEMENT

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Pornprom Pahubutra is a graduate student at the Mechanical Engineering Department, Thammasat School of Engineering, Thammasat University, Thailand. He is intersted in Mechanical Devices and Experiment.

Dr. Dulyachot Cholaseuk is an Associate Professor at the Mechanical Engineering Department, Thammasat School of Engineering, Thammasat University. He obtained his Bachelor of Engineering degree (Mechanical Engineering) from Chulalongkorn University, Thailand. He earned his Ph.D. (Mechanical Engineering) from Columbia University, New York. His research interests include Robust Optimum Design of Mechanical Parts and Systems, Shape and Topology Optimization, Design of Foldable Vehicles, Biomimetics.