

Multibody Mechanical Model and Simulation of Rocking Suitcases

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Summary. The stability and the rocking motion of two-wheeled suitcases are analysed in this study through numerical investigations and measurements. A simplified mechanical model is presented, the governing equations are derived for all the motion states of the suitcase and an impact model is also defined to realize switching between these states.

Introduction

The stability of suitcases is an important and irritating problem of everyday life as two-wheeled suitcases are often used for travelling. As known, a suitcase can start to rock if large enough perturbation occurs, and in crucial cases the suitcase overturns. The topic is so significant that it is researched in high quality scientific journals even nowadays, see [1–3]. The interest of researchers is supported by the fact that similar stability problem of trailers exists in vehicle dynamics.

In mechanical point of view, the analysis of the rocking suitcase problem is very fascinating. On the one hand, the system is non-smooth as different equations describe the different motion states (i.e., rolling on two wheels, rolling on one of the wheels or non of the wheels having contact with the ground). On the other hand, in case of contacting wheel, the spatial motion of the suitcase is influenced by the kinematic constraints, which makes the derivation of the equation of motion more complicated. In this study, we analyse the system through numerical and experimental methods.

The simplified mechanical model

The simplified mechanical model is depicted in Fig.1. The suitcase is pulled with constant speed v by the ball-joint at A. The body of the suitcase is assumed to be rigid and it is modelled by means of massless rods and by a lumped mass m at its center of mass C. One can describe the position of the mass with parameters e and f . The length and the width of the suitcase are described with the parameters l and $2b$, respectively, while h is the distance between the towing point A and the ground. The radius of the wheel (r) is assumed to be zero, which is a suitable approximation in our simplified model.

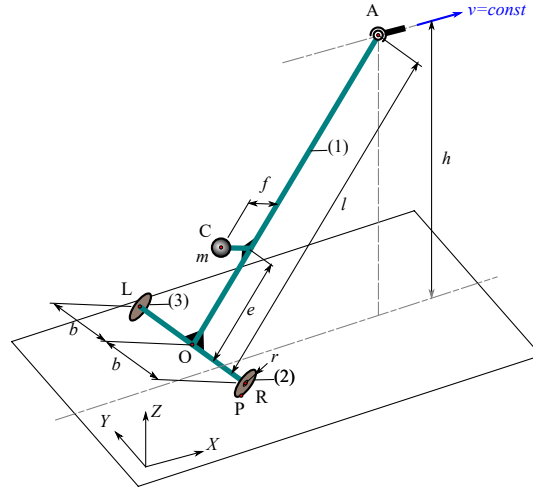


Figure 1: The simplified mechanical model of a towed suitcase.

There are four different motion states: both wheels contacting the ground, one wheel (right or left wheel) is on the ground, none of the wheels is on the ground. The different states corresponds to 1, 3 or 6 degrees-of-freedom mechanical models.

When both wheels are on the ground, the suitcase makes in-plane motion and the equations of motion can be easily derived. Having only one wheel on the ground is the most intricate case, the motion is spatial while the kinematic constraint of rolling has to be considered. If none of the wheels have contact

with the ground, the motion is spatial but the system simplifies to a spatial mathematical pendulum. To make switches between the motion states, a complex impact model is sufficient since classical rigid body impact models could not be used to describe the practically observed transitions between the different states of motion.

Measurements

Measurements were carried out to investigate the motion of the suitcase. A simplified construction of the suitcase was designed and built and was towed on a conveyor belt, see Fig. 2. We analysed the effect of the initial conditions and parameters e , f and h on the stability meanwhile the speed was changed in small proportions from 0.5 km/h to 18 km/h.



Figure 2: The experimental rig.

The measurements showed that all the four motion states could be detected and the effect of the parameters f and h are relevant. The stable speed range is larger if these parameters are chosen to be smaller.

Numerical investigation

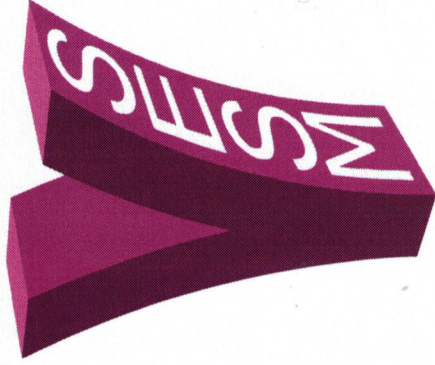
The governing equations and the impact model were implemented in computer code, in additional, simulations were run for different initial conditions and parameters. As all the motion states had different number of degrees of freedom, the coupling between them is a difficult problem. By means of the numerical investigation, the domain of attraction of the rectilinear motion can be identified.

Conclusions

A simplified mechanical model of rocking suitcases was constructed and the equations and motion of the different motion states were derived. The numerical investigation of these equation can result important information about the nonlinear behaviour of the suitcase. Experimental rig is also ready to validate these results and provide basic rules that can help the design of suitcases having better stability properties.

References

- [1] Facchini, G., Sekimoto, K., Courrech du Pont, S.: The rolling suitcase instability: a coupling between translation and rotation. In: Royal Society, 473(2202). 2017.
- [2] Plaut, R. H. : Rocking instability of a pulled suitcase with two wheels. In: Acta Mechanica 117. 1996. 165-179. p.
- [3] Suherman, S., Plaut, R.H., Watson, L.T., Thompson, S.: Effect of Human Response Time on Rocking Instability of a Two-wheeled Suitcase. In: Journal of Sound and Vibration, 207 (5). 1997. 617-625. p. Computers and Information in Engineering Conference, Long Beach, California, USA, September 24-28, 2005. Paper No. DETC2005-84574. 1-12. p.



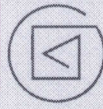
16th Youth Symposium on Experimental Solid Mechanics
May 17th - 19th 2018, Traunkirchen, Austria

CERTIFICATE OF ATTENDANCE

Hanna Zsófia Horváth

Budapest University of Technology and Economics
Hungary

Organisation committee



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May 17, 2018

7:00 - 8:00	travel to Traunkirchen
8:00 - 8:30	Registration
8:30 - 9:30	1st Lecture (Brian Steinhobel)
9:30 - 10:30	2nd Lecture (Prof. Ludovic Noels)
10:30 - 11:00	Coffee break
11:00 - 12:00	3rd Lecture (Dr. Fabian Grasse)
12:00 - 12:30	discussion with lecturers
12:30 - 13:30	Lunch break
13:30 - 14:30	4th Lecture (Dr. Stephen Hall)
14:30 - 15:30	5th Lecture (Dr. Stephan Vervoort)
15:30 - 16:00	coffee break
16:00 - 17:00	6th Lecture (Prof. Lucien Laiarinandrasana)
17:00 - 17:30	discussion with lecturers
18:00 - ?	Dinner

May 18, 2018

8:30 - 9:30	Oral Presentations - 5 presentations
9:30 - 10:15	Poster presentations + discussion
10:15 - 10:30	Coffee break
10:30 - 11:30	Oral Presentations - 5 presentations
11:30 - 12:15	Poster presentations + discussion
12:15 - 13:45	Lunch break
13:45 - 14:55	Oral Presentations - 6 presentations
14:55 - 15:40	Poster presentations + discussion
15:40 - 15:55	Coffee break
15:55 - 17:05	Oral Presentations - 6 presentations
17:05 - 17:50	Poster presentations + discussion
18:30 - ?	Dinner

May 19, 2018

8:30 - 9:30	Final discussions
9:30 - 13:00	Social activity
13:00	Closing + departure

8:30 - 9:30	Oral Presentations - 5 presentations	Thermomechanical behavior of metal-polyurethane bonded joints Human balancing on rolling balance board Shape Optimization of the fillet under the bolt T-head Multibody Mechanical Model and Simulation of Rocking Suitcases Numerical modelling of compressive characteristics of auxetic structures
	Marina Ragni	
	Csenge Molnár	
	Andrea Sorrentino	
	Hanna Zsófia Horvath	
	Michaëla Neuhäuserova	
10:30 - 11:30	Oral Presentations - 5 presentations	Modelling and Simulation of Lattice Structures using various Material Models for Polymeric Materials Micromechanics based progressive failure modelling Topology optimization for automotive components Experimental and numerical investigation of Polypropylene compounds for instrumented puncture test Short and long term mechanical behaviour of 3D-printed materials for robotic applications
	Kerstin Lehner	
	Emil Pitz	
	Florian Dirisamer	
	Florian Kiehas	
	Michael Lackner	
13:45 - 14:55	Oral Presentations - 6 presentations	Comparison of idealized experimental tests and loadings during real life application of a complex automotive component Characterization of the Fracture Mechanical Behavior of C-SMC Materials Instrumentation of Split Hopkinson Pressure Bar for Testing of Cellular Metallic Materials Instrumentation of Four-point Bending Test during 4D computed tomography Preprocessing of Hopkinson Bar Experiment Data: Filter Analysis Testing of Hybrid Nickel-Polyurethane Foams at High Strain-Rates using Digital Image Correlation
	Andreas Pröll	
	Martin Tiefenthaler	
	Jan Falta	
	Daniël Kytýr	
	Marcel Adorna - 2 presentations	
	Marcel Adorna - 2 presentations	
15:55 - 17:05	Oral Presentations - 6 presentations	Multi-Channel Control System for In-situ Laboratory Loading Devices Effects of physical ageing within creep and relaxation tests for a multiaxial isotropic viscoelastic characterization of epoxy resins Basic biomechanical characterization of polyurethane based artificial cancellous structures Influence of printing and loading direction on mechanical response in 3D printed models of human trabecular bone Optimization of Decompressive Craniectomy Based on Finite Element Simulations Mechanical Behaviour of Multi-Ring Masonry Arches
	Vaclav Rada	
	Michael Milka	
	Jan Šleichrt	
	Tomáš Doktor	
	Máté Hazay	
	Tamás Forgács	