Nat. Hazards Earth Syst. Sci. Discuss.,
https://doi.org/10.5194/nhess-2018-108-AC2, 2018

Natural Hazards and Earth System Sciences
Discussions

Interactive comment on "Effects of the impact angle on the coefficient of restitution based on a medium-scale laboratory test" *by* Yanhai Wang et al.

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Received and published: 7 July 2018

I, on behalf of other co-authors, would like to express our gratitude for the reviewer's attitude towards the reviewing.

General comments: The article presents a laboratory study on the dependence of the coefficient of restitution regarding the impact angle, falling height etc. Based on the results a regression has been formulated to obtain normal and tangential coefficients of restitution. The R2 are not very high. This – in my opinion – has one main reason: the blocks are not spherical but have edges an corners. Their impact on the ground mains defines the rebound angle and velocity. The model itself cannot reflect this

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Discussion paper

effect because it neglects the rotational movement of the block that has a significant influence. Therefore, the model presented should be reported as being valid only for trajectory simulation codes based on point masses used to simulate the blocks. The model would not work for simulation codes that use folly shaped three-dimensional blocks. This should be stated in the introduction, handled in the discussion and be summarized in the conclusions.

Reply: Thanks you very much for your comments! In this study, the free fall tests are performed and the sample impacts the slope without rotation. When the sample leaves from the slope, the rotation is observable and the angular velocities are also recorded. Just as you indicated, the angular velocities are not involved in the previous manuscript because the assumption of a lumped-mass model is adopted in this study. Considering the comments by all reviewers, the rotation is involved in evaluating the effect of the impact angle on the coefficients of restitution. Results show that the percentage of kinetic energy converted to rotational energy increases as the impact angle decreases, and large samples are more likely to have a stead and small percentage than small samples. And a higher percentage of kinetic energy converted to rotational energy always induces a higher normal coefficient of restitution Rn and a lower tangential coefficient of restitution Rt. Although the impact orientations during impact are not involved in this study, the results may be useful for those codes based on a rigid body model when predicting the trajectory of spherical rocks with rough surface.

The main changes in manuscript: Considering all comments, the structure of this paper is rearranged. All figures are modified and rearranged. The purpose of this study is described as: (1) to verify whether the test scale influence the laws regarding the effect of the impact angle on the coefficients of restitution, (2) to determine the role of rotation in the effect of the impact angle on the coefficients of restitution. Rotation is involved in this study. As a consequence, the kinetic energy coefficient of restitution RE is recalculated, and results of the kinematic coefficient of restitution Rv is added in this study. The fitting curve are replaced by mean value lines of data points, and

the fitting formula is removed. In the original manuscript, we considered the impact velocity difference as the main reason for the magnitude difference in the coefficients of restitution between the tests compared. In the revision, we withdraw this deduction. The role of rotation in the effect of the impact angle on the coefficients of restitution is investigated. As the percentage of the total kinetic energy converted to rotational energy increases, Rn increases but Rt decreases. The percentage increases as the impact angle decreases, and large samples are more likely to have a stead and small percentage than small samples.

To special comments P1L13: Please, add short term on the kind of rock movements with or without rotation, "jumping" or vertically falling. Reply: As your suggestion, we have rephrased the sentences. "Free fall test are conducted and the velocities before and after the impact are obtained by a 3D motion capture system." The rotation is little before impact, but is observable after impact.

P2L4: Outdated references! Reply: Thanks you a lot! The simulation codes listed in the previous paper is too outdated and cannot reflect the new progress. We have inspected literatures till 2018 and some representative simulation codes are added in the revised manuscript.

P2L19: The COR is a model only. In reality it is almost zero. Example: take a spherical rock and let it fall –> it barely jumps. Reply: You are right! The coefficients of restitution is only useful for the bouncing phenomenon. When computer simulation codes are adopted in the trajectory predication, the coefficients of restitution should be input by users. Some typical values has been recommended for normal and tangential COR values according to the slope properties, such as clean hard rock, bedrock outcrops with boulders, and so on. Some summary work was listed in this paper, which may benefit some readers. As the structure of the paper is rearranged, the related sentence is removed to the end of Section 1.1, "So, Rn and Rt attracted most attentions in the previous studies, and some typical values of Rn and Rt had been summarized (Agliardi and Crosta, 2003; Heidenreich, 2004; Scioldo, 2006)."

P4L23, P9L14, P16L8: replace “increases in the impact” by “increasing” Reply: Thanks you for your suggestion! The expression has been revised as your suggestion.

P5L2: Glover also evaluated coefficients of restitution in http://etheses.dur.ac.uk/10968 Reply: Thanks you very much! James Glover did excellent works on how the shape of rock affect the rockfall dynamics. And we noticed that some results about the effect of the impact angle were also presented in the thesis, which has been added in the Section 1.2.

P5L12: use kg instead of g because it is doubtful that exact this weight is kept. Reply: Thanks you for your suggestion! The expression has been revised as your suggestion.

P7L5: 60fps might not be enough precise to capture the accelerations (during impact= time of the highest acceleration) there are only very small displacements that are not covered by the resolution of the cameras? Reply: Thanks you a lot! We inspected the data information and found that the accelerations are not provided by the system. In the revision the “accelerations” has been removed.

P12L8: Of course, if only translational movements are looked at. The hardness of the impact partners involved is not very relevant. The rebound is influenced mainly from the rock’s edges and therefore related to its rotational movement. Reply: You are right! In the revised manuscript, the title of related figure is revised as “Direction transitions of translational velocities induced by impacts” and the related sentences is rephrased. The impact orientations, a corner contact or an edge contact, will affect the rebound motion. In the revised manuscript, the rotation is involved.

P13L7: This is a very precise weight.... Reply: Yes, it is a quite precise value. We inspected Chau’s article “Coefficient of restitution and rotational motions of rockfall impacts, Int J Rock Mech Min Sci, 39, 69–77, 2002” again. And the weight is given clearly in the literature. So, we keep the value unchanged.

P16L30: "Assume" –> "Assuming" Reply: Thanks you for your suggestion! The ex-

pression has been revised as your suggestion.

P20L9: The presented concept of COR analysis an experimental/laboratory trajectory regarding the block's center of gravity. The shape of the block does not play any role as well as its rotational movement. The presented model to determine Rn therefore only works if the trajectory model simulates small mass points without rotational movements. As soon as the trajectory code aims to model spatially shaped blocks with edges and corners above data cannot be used. This consequence should be added to discussion and conclusions. Reply: In the previous paper we didn't point out that the assumption of a lumped-mass model in the study. Considering all comments, the rotation is involved in the revised paper, and its role in the effect of the impact angle is investigated. In this study the surface of samples are constituted by small artificial facets, the impact orientation can't be distinguished during the collision. Although the orientations of the block during impact are not involved in this study, the results maybe useful for those codes based on a rigid body model when simulating the trajectory of spherical rocks with rough surface.

References: Reply: Thank you very much for your reminding! We have inspected the details and formats of the references. Some new literatures are added according to the revision, and a unify format is used.

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Please also note the supplement to this comment:
https://www.nat-hazards-earth-syst-sci-discuss.net/nhess-2018-108/nhess-2018-108-AC2-supplement.pdf

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Interactive comment on Nat. Hazards Earth Syst. Sci. Discuss., https://doi.org/10.5194/nhess-2018-108, 2018.