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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.

**Yanhai Wang et al.**

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

General comments: This is a good set of experiments. I encourage the authors to take some time to improve their manuscript. Here some comments that can be useful. Reply: Thank you very much for your encouragement! To date, restrained by the measure devices, the existing laboratory test are mainly small scale tests. The initial purpose of this study is to investigate whether the existing conclusions regarding the effect of the impact angle on the coefficients of restitution are valid when the test scale



changes.Considering comments by all reviewers, the rotation is involved in this study. And, in the new manuscript, the role of the rotation in the effect of the impact angle is also investigated. Because the magnitudes of the total kinetic energy before impact varies, the percentage of the total kinetic energy converted to rotational energy is used as a reference. Results show that the percentage increases as the impact angle decreases, and large samples are more likely to have a stead and small percentage than small samples. A higher percentage always induces a higher Rn and a lower Rt. While, no clear correlations occurs between the percentage and the other two coefficients, Rv and RE. In the revised manuscript, this has been listed as another contribution of this study.

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 LINE 4 PAGE 4. Please note that this RE value omits the rotational kinetic energy and as such, it simplifies the description of the collisions. I do

expect that your spherical polyhedrons rotated both before and after their impacts. This should be mentioned in the discussion since it affects the plot in Fig 8. For example, in our experiments (Cagnoli and Manga, 2003), our cylindrical particles did have a rotational kinetic energy but only after the collision with the target as the high-speed video camera confirmed. Reply: Thank you very much for your suggestions! Considering comments by all reviewers, the rotation is involved in the calculation of the energy coefficient of restitution RE in the new manuscript, and the role of rotation in the effect of the impact angle on the coefficients of restitution is investigated. In this study, the samples has little rotation before impact, while has the observable rotation when leaving the slope.

LINE 18 PAGE 5. I think that a drawing of the apparatus with vertical and horizontal length scales would improve the readability of the paper. Reply: Thank you very much for your suggestions! A general view of the apparatus has been added in the revised manuscript. All figures are rearranged according to their logical link, and some figures are merged.

FIG 8 PAG 11. Here, it seems to me that you felt the obligation to have to find one single best-fit curve even if your data points illustrate a much more complex situation. Rather than concave-down best-fit curves (which are truly not convincing), this plot shows two features: 1) the maximum values decrease as the impact angle increases and 2) the spread of the data points decreases as the impact angle increases. This is true for both your grain sizes. We obtained these same features as shown by Fig 4A in Cagnoli and Manga (2003). I strongly suggest to remove these concave-down curves because they are truly misleading. Reply: Thank you very much for your reminding! Considering comments by all reviewers, the best-fit curve is replaced by the mean value line for data points in the related figures in the new manuscript. Considering the discreteness in data points, a general trend is more appropriate than a fitting cure to illustrate the effect of the impact angle on the coefficients of restitution.

FIG 9 PAG 11. It would be useful to identify in this figure each experiment with its



own characteristics. Reply: Thank you very much for your reminding! In the new manuscript, two markers are adopted to represent data points for two sample sizes, respectively. And the original “45o line” is renamed as “$\alpha$=$\beta$ line” considering other comments.

TABLE 2 PAG 13. Please note that our cylinders are 0.89 cm long and with a basal diameter equal to 0.55 cm (Cagnoli and Manga, 2003). However, rebound angles of larger cylinders are also shown in Fig. 2A. Reply: Thank you a lot! In the new manuscript, the size of the cylinders are noted in Table 2.We noticed that the rebound angles of larger samples are presented in your excellent paper. It is not involve in the results comparison because the results comparison focuses on the effect of the impact angle on the coefficients of restitution. In Section 4.1 “Direction transitions of translational velocities”, we noted that your test also observed this phenomenon.

LINE 9 PAG 13. The rebound angles can be larger than the impact angles for two reasons. First, the surface of your concrete slabs cannot be perfectly flat in particular after the target has been damaged by previous impacts. Second, the surface of your particles has a curvature that varies from place to place (i.e., they have edges and corners). In other words, the true impact angle is not known. In our Fig 2A, some rebound angles are also larger than the impact angles. Even if this seems to be a flaw of the experiments, it has to be accepted as the inevitable complexity of rock fragment collisions and it is still useful to understand this complexity. For this reason, it is not correct to exclude what you call “non-ideal data points” when computing best-fit curves. The truth is that a single best-fit curve of the entire set of data points in Fig 8 does not exist. You can plot only a trend line for the maximum values if you really want to. Reply: Thank you very much! In the revised manuscript, all data points are reserved. It is unreasonable to exclude those “non-ideal data points” for a better fitting curve. Considering comments by all reviewers, the mean value line for data points is adopted in the new manuscript.

FIG 11 PAG 14. Please, remove curves 5 from Figs 11a, 11b and 11c, because, in

nature, beta can be larger than alpha. Do Figs 11a and 11b display mean values? If yes, state this clearly. In Figure 11c, draw only curves showing the maximum RE values. Reply: Thank you for your reminding! All data points are reserved in the revised manuscript, so curve 5 is removed naturally. Considering comments by all reviewers, the mean value line is adopted to represent the trend for our study. The meaning of every trend line for the tests compared and our study in figures are stated in the new paper.

LINE 3 PAG 15. What you say here is true. However, I would rephrase the sentences. The small Rn values in Cagnoli and Manga (2003) are due to the weak strength of pumice whose damage upon impact dissipates energy. Reply: Thank you a lot! In the new manuscript, the sentence has been rewritten as your suggestion.

LINE 25 PAG 15. What do you mean with “nadir”? Please find a more appropriate word. Reply: I am very sorry for the inexact word used. Actually, in the original manuscript, we noticed that when the impact angle is less than 40o, your test provided the lowest Rt. And it increases as the impact angle increases. We considered the impact velocity as the main reason for the magnitude difference in the coefficients of restitution between different tests. However, in the new manuscript we didn’t make a determined conclusion about this. Multiple factors can affect the magnitude, thus, it is unreasonable to appraise the effect of one specific factor on the magnitude of the coefficient of restitution using data from the tests under various conditions together.

LINE 30 PAG 15. As explained above, curve 1 in Fig 11c is not useful and should be removed from the plot. Reply: Thank you for your reminding! Considering comments by all reviewers, the mean value line is adopted to represent the trend for our study.

LINE 8 PAGE 16. This is not correct. Both your Fig 7 and our Fig 3B confirm that Rt increases as the impact angle increases. The problem is that the data spread is large. But this is due also to irregularity on the surfaces of target and particles, for example. Reply: You are right! One purpose of this study is to verify whether some general



laws occur when accounting for the effect of the impact angle, regardless of the test scales and conditions. The results comparison shows that the tangential coefficient of restitution Rt increases as the impact angle increases in most cases.

LINE 21 PAGE 16. This is the same explanation we have provided in our paper (see our Fig 1), but no credit is given. Reply: I am very sorry that more detailed information, such as the erosion depth caused by each impact and the impact orientation during each collision, is not recorded when performing the test. In the new manuscript, one figure of the damaged surface is provided as a credit in Discussion.

LINE 18 PAGE 18. The use of the coefficient of restitution does not provide a good description of rock fragment collisions. But credit should be given to who has already said it (e.g., Stronge, 1991). Both your and our data sets show that: 1) there is no such as thing as a single value of the coefficient of restitution, and 2) also the more informative ratio of the kinetic energy is not a constant. Reply: Thank you very much! In the revised manuscript, Stronge’s conclusion has been cited as a credit, and the paper has been listed as a reference.

Please also note the supplement to this comment:
https://www.nat-hazards-earth-syst-sci-discuss.net/nhess-2018-108/nhess-2018-108-AC3-supplement.pdf

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