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Natural Hazards and Earth System Sciences
Discussions

Interactive comment on "Comparing Thixotropic and Herschel-Bulkley Models for Avalanches and Subaqueous Debris Flows" *by* Chan-Hoo Jeon and Ben R. Hodges

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1. The authors should be defined/explain them (classification of submarine landslides) in the manuscript: What is the difference from avalanche and debris flow. In Page 10, line 17-18, the avalanches were explained, but not for subaqueous debris flow.

   We have added the definitions in the introduction on pg 2, lines 6-8 as:

   –"Avalanches (e.g. snow, rock) are typically considered dry granular flows, whereas debris flows are liquid/solid mixtures where the solids are a dominant forcing, which can be contrasted to flood flows where sediment solids play a secondary role (Iverson,1997)."

   We have also tried to clarify how we are treating these disparate flows similarly on pg 2, lines 24-27

   – "Herein, we do not seek to distinguish between the differing physics of these various complex flows, but focus on advancing the use of non-Newtonian viscosity models as a proxy for their general behavior. For simplicity in exposition, we will use the term "debris flow" to refer to any real-world mixture modeled as a continuum fluid using a non-Newtonian model."

2. In reality, actual subaqueous debris flows are run with large-sized particles during debris flow motion.

   We have combined the answer to this comment with the answers to comment (3), see below.

3. Please explain the role of clays contained avalanche/debris flow/mudslides in subaqueous environment and how they influence upon the landslide motion.

   We have combined the answer to this comment with the answer to comment (2). These comments are also similar to the comments (1) and (2) of Reviewer 2. The reviewers have pointed out a problem in the way we presented the paper in the introduction. Comments (1) and (2) involve the specific physics of debris flows associated with real-world particle sizes and physics of clays. Our original paper was not sufficiently clear in the abstract and introduction: we are not intending to look at the physics of these flows, but instead are focused on the way in which previously-used models might be improved by adoption of thixotropy in a non-Newtonian approach where viscosity is a proxy for all the complex physics. As such, we do not believe it is appropriate to get into a detailed discussion of the physics that are only approximated in their effects by a non-Newtonian model. We have significantly rewritten the abstract and introduction to make this clearer. This includes pg 2, lines 1-27 and lines 30-32, along with minor clarifications throughout page 3. In particular, see pg 2, lines 22-27, where we provide the reader with references for the physics and place our work in a clearer context:

– "We take these issues as motivational for the present work and refer the reader to the recent review of Delannay et al. (2017) for further insight on granular flows and Shanmugam (2015) for heterogenous flows. The fundamentals physics of such flows is presented in Iverson (1997). Herein, we do not seek to distinguish between the differing physics of these various complex flows, but focus on advancing the use of non-Newtonian viscosity models as a proxy for their general behavior."

Thank you for these comments as they helped us significantly improve the introduction to the paper.

4. No conclusions in this paper?

   Our conclusions were integrated in the prior Discussion section. We have modified the name to "Discussion and Conclusions" as it contains both the summary of the results and observations as to the impact of the two sets of results taken together. Note that additions to the closing paragraph have been provided to provide better insight into how this work could be extended in the future. See pg 26, lines 22-31:

   – "For time-dependent thixotropic models to be useful in modeling real-world avalanches and debris flows, there is a need for a consistent approach to defining the initial jamming (λ_0), the characteristic time of aging (T_0), and the asymptotic shear viscosity (η_0), along with the material parameters ω and α for real-world systems. As yet, these parameters are not well-defined for either simple laboratory models or complex real-world flows. To improve our understanding of the thixotropic model, there is a need for a comprehensive sensitivity analysis of these five driving parameters for the expected scales of real-world systems (which are as yet unknown). Furthermore, with or without the thixotropic model, there is clearly a need for (1) more detailed experimental measurements during flow initiation and restructuralization, and (2) a better understanding of the relationship between measurable microstructure parameters and the effective stress-strain relationship. The present work shows that a time-dependent (thixotropic) viscosity model may be an effective proxy for representing the inception and stalling of an avalanche or debris flow, but

   much work remains to be done before real-world natural hazards can be modeled in this manner."

5. Page 2, line 6, 19 (moller et al.) should be checked with page 7, line 16.

   We have made citations to "Møller et al. (2006)" consistent with the spelling in that paper. Note that the citation to "Moller et al. (2009)" is also consistent with the spelling in that paper as the latter did not include the ø in the author's name.

6. Page 2, line 23, yield stress vs page 23, line 2 yield-stress

   We have corrected the paper for consistent grammar throughout. Where we use "yield-stress fluid" we include the dash as "yield" modifies "stress" rather than "fluid" such that "yield-stress" is a compound adjective. However, where we write "yield stress" with stress as a noun, there is no need for a dash.

7. Page 6, line 18 ODE (9): ODE (Eq. 9)?

   Modified to "the ordinary differential equation presented as Eq. (9)".

8. Page 7, lines 7, 8: Session 6 , Session 7?

   Modified the symbol "§" to "Section" throughout the paper.

9. Page 12, Fig. 3: the shape of landslide is triangular? Why not for parabolic shape? Any reason?

   The shape was chosen to match initial conditions of prior experiments in the literature. In the experiments, a retaining gate is opened and the avalanche starts to flow. During the flow the shape tends toward parabolic.

10. Page 15, Fig. 7: x-axis of nondimensional time (t*) is the time scale for the landslide initiation or landslide motion or debris flow propagation?

    The time scale denotes the simulation time (t) after gate opening. It is non-dimensionalized by the gravity (g) and the initial height normal to the bottom (d_0). In

other words, it is the time of flow motion (landslide or debris flow). To make this clear, we added some description for this to the manuscript, see page 16, lines 2-3:

– "... the non-dimensionalized front location and **simulation** time **after gate opening** are..."

We also added "simulation time" to captions of figures 7, 8, and 9.