Response to the first referee

Dear Editor and Reviewer:

Thanks very much for your careful review and constructive suggestions on the manuscript "Estimation of flow velocity for a debris flow via the two-phase fluid model" (npg-2014-39). We have revised the manuscript carefully according to reviewers' comments. The detailed revisions are listed below based on reviewer's response point by point.

Qu. 1 Introduction: In the second § it does not become clear whether ta two layer system (slurry and dense fluid-solid mixture is looked at.

The three stated assumptions are extremely restricting:

(1) No geometric deformation of the moving mass is possible

(2) What is meant by that 'no external materials are involved' [do you mean erosion and deposition] and there are 'no transformations between the solid and the liquid phases' [Do you mean that no phase changes occur?]

(3) Steadiness. This is almost never the case.

Ans. In this article, "the solid phase" denotes "the solid phase particles", "the liquid phase" denotes "the liquid phase slurry". We have change "the solid phase" and "the liquid phase" into "the solid phase particles" and "the liquid phase slurry" respectively. 'no external materials are involved', that is, both sides bank slope of the debris flow groove doesn't supply materials, the debris flow keep balance in the groove. 'no transformations between the solid and the liquid phases', which means that no transformation between the solid phase particles and liquid phase slurry. To deal with the velocity of a debris flow is a quite complicated process. For convenience of calculations, we assume that a debris flow is steady (see [1-3]).

Qu. 2 For the presentation of eqs. (1)-(4) it should be said that the two phases are density preserving and the mixture is saturated.

Ans. This is explained in our assumption. A homogeneous flow and no transformation between the solid phase particles and liquid phase slurry guarantee that the two phases are density preserving, and no external materials are involved guarantees that the mixture is saturated.

Qu. 3 Equations (5), (6): I do not understand the term 'surface forces' I would interpret fs and ff as interaction forces between the phases, and fs+ ff= 0 would be required. Is this satisfied?

Ans. In the movement of a debris flow, taking which in a unit volume as the research object, which is said to be control volume. On surface of control volume, there exists the acting forces from debris flow outside control volume, it is said to be surface forces. Here, the surface forces ($f_{\mathrm{s}x}$ and $f_{\mathrm{f}x}$) in a unit volume beyond pressure are considered. Since the debris flow is divided two phases: the solid phase particles and liquid phase slurry, the surface forces of the solid phase $f_{\mathrm{s}x}$ on control volume is divided into two parts: the traction of liquid phase slurry outside control volume, $f_{\mathrm{s}x1}$, and the force from solid particles outside control volume, $f_{\mathrm{s}x2}$; the surface forces of the liquid phase $f_{\mathrm{f}x}$ on control volume is divided into two parts: the resistance from particles outside control volume, $f_{\mathrm{f}x1}$, and the resistance from liquid phase slurry outside control volume, $f_{\mathrm{f}x2}$. It can be seen that $f_{\mathrm{s}x1}$ and $f_{\mathrm{f}x1}$ are a pair of interaction forces between the phases, and they satisfy $f_{\mathrm{s}x1} + f_{\mathrm{f}x1} = 0$.

Qu. 4 Equation (7): Is v the barycentric velocity? Is there any literature reference for the value of k, given after eq. (8)?

It is not clear in this context what a 'viscous debris flow' is against a 'thin debris flow. Please be precise.

Ans. Yes, ν is the barycentric velocity, the non-uniform coefficient k can been in [4, pp. 177-178] and we have added the ref. in our manuscript. In [4, pp. 177-178], the non-uniform coefficient k is about 2.4–3.0 for a viscous debris flow; k is about 3.0–3.5 for a transitional debris flow; k is about 3.5–4.0 for a thin debris flow. We have changed "the non-uniform coefficient k is about 2.4–3.0 for a viscous debris flow, whereas k is about 3.5–4.0 for a thin debris flow" into "the non-uniform coefficient k is about 2.4–3.0 for a viscous debris flow; k is about 3.5–4.0 for a thin debris flow (see [4])". We mainly consider both the viscous and thin debris flow, the transitional debris flow don't been involved.

Qu. 5 Equation (11): Is *vbar* in this equation the same as v?

Ans. ν is the velocity of debris flow, whereas $\bar{v}$ is the velocity of the debris flow in x direction.

Qu. 6 Text and equations between eqs. (13)-(18): This text needs to be revised. It does not become clear what 'outside control volumes' etc. mean. Perhaps the authors mean the volume of the pore space or the 'grain area wetted by the fluid'.

In the text from (13)-(18) twelve articles 'the' are missing and after eq. (15) 'the pressure difference' is NOT 'generated' but 'is acting'. Moreover, it is not clear, how the two choices of P_0 and T_0 in the un-numbered equations are connected. No hints or references are given.

Ans. The explanation regarding control volume can be seen in the response of Qu. 3. We have added the articles 'the' and replace 'generated' by 'is acting'. The two choices of P_0 and T_0 in the un-numbered equations can be seen in [5,6].

Qu. 7 What is a 'framboid'? (top on page 5) Please also explain the meaning of l. Is it the boundary layer thickness around the grains?

Ans. We have changed 'framboid' into 'eddy', l is the mixing length among flow layers in the debris flow body, that is, the moving distance of eddies in the liquid phase slurry, which is caused by the effect of the fluctuating velocity.

Qu. 8 It is stated on top of page 6 down to eq. (23) that 'the turbulence parameter η and the velocity profile parameters a, b, c must be determined experimentally determined. But how is this done? Please explain, the formulas ought to be useful.

Ans. The turbulence parameter η can be taken as Karman constant [6]. The velocity profile parameters a, b, c are obtained through the experimental simulation based on the analysis and study of the sampled debris flow deposits.

Qu. 9 Text between eqs. (23) and (24). Here all of a sudden 'the velocity of the solid phase in the y-direction and the effect of the turbulence in the slurry are ignored'. Everything from eqs. (24)-(35) is then restricted to this simplification. Can we then simply forget the text between eq. (20) and eq. (23)?

Ans. In the process of a debris flow movement, including the forward flow along the debris flow groove and the vertical turbulent in the debris flow body, however, from velocity analysis of the debris flow, especially the impact and abrasion of the debris flow for the controlling structure and bank slope, the forward movement of the debris flow is mainly concerned (see [6]). Hence, we mainly consider the velocity of the solid phase in the x-direction, the effect of the turbulence in the slurry isn't considered, i. e. we can regard η as 0, then $f_{\mathrm{f}x2} = a\mu d_0^2 + (\tau_{\mathrm{B}} + \mu b)d_0$. Further, for the convenience of calculation, we will take linear distribution of velocity of the liquid phase slurry with respect to y [6] as an example. So that, it follows that $f_{\mathrm{f}x2} = (\tau_{\mathrm{B}} + \mu b)d_0$.

Qu. 10 Can you explain in a few words how eq. (32) is solved to obtain eq. (33)?

Ans. Let $y = \frac{\rho_{\mathrm{s}} v_{\mathrm{s}x}^2 - \rho_{\mathrm{f}} v_{\mathrm{f}x}^2}{2}$, $A = -\frac{3k}{(2k+1)(1-\varphi)d_{\mathrm{e}}}$, $B = -\frac{1}{2k+1}[(2\rho_{\mathrm{f}} - \rho_{\mathrm{s}})g\sin\theta + (\tau_{\mathrm{B}} + \mu b)d_0]$. Then Eq. (32) becomes

$$\frac{\mathrm{d}y}{\mathrm{d}x} = Ay + B.$$

By separation of variable, it follows $y = \frac{-1}{A}(e^{(x+C)A} + B)$, where C is the undetermined constant. From $y = 0$ as $x = 0$, it has $e^{CA} = -B$, thus $y = \frac{B}{A}(e^{Ax} - 1)$.

Qu. 11 3. Results and discussion: Can you explain how eqs. (38), (39) are derived (from (36), (37)) and how the un-numbered equations for the squared velocities of the solid and fluid are deduced.

Ans. The original manuscript: Eqs. (38) and (39) are derived from Eq. (33). This is hinted below Eq. (37) ("However, Eq. (33) provides the kinetic energy difference between two phases"). The un-numbered equations for the squared velocities of the solid and fluid are obtained from Eqs. (34), (36)-(39) and (35), (36)-(39), respectively.

Qu. 12 Introduction line 14: brush→ bush
3 lines before 4 Conclusions: locale → location

Ans. We have replaced 'brush' and 'locale' by 'bush' and 'location', respectively.

References

[1] Chen, C.: Generalized viscoplastic modeling of debris flow, J. Hydraul. Eng., 114, 237–258, 1988.

[2] Chen, H., Tang, H., Ma, Y., and Wu, S.: Research and Control of Debris Flow Along Highway, China Communications Press, Beijing, 86–116, 2004 (in Chinese).

[3] Jan, C.-D. and Shen, H. W.: Review dynamic modeling of debris flows, Lect. Notes Earth Sci., 64, 93–116, 1997.

[4] Chen, N., Yang, C., Zhou, W., Hu, G., Deng, M., Yang, K.: Investigation Technology For Debris Flows, Science Press, Beijing, 177-178, 2011 (in Chinese).

[5] Bagnold, R. A.: Experiments on a gravity-free dispersion of large solid spheres in a Newtonian fluid under shear, Proc. R. Soc. Lond. Ser. A, 225, 49–63, 1954.

[6] Chen, H., Tang, H., and Chen, Y.: Research on method to calculate velocities of solid phase and liquid phase in debris flow, Appl. Math. Mech.-Engl., 27, 399–408, 2006.

We would highly appreciate if you could take necessary action.

Looking forward to hearing from you.

Best wishes to you!

Yours sincerely,

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