Flow Regimes in Horizontal Viscous Dam-Break Flow of Clayous Mud

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Abstract:
The main characteristics of geological flows such as debris flows, avalanches and lahars is due to the relative importance of viscous versus inertial forces in the momentum balance. This paper considers the motion generated by the collapse of a dam-retaining mud, itself modeled as a power-law fluid. The equation of motion is derived in a non-dimensional form and solved analytically with the shallow-water assumption in a dry and smooth horizontal channel. Notably indicated are flow regimes and the effect of the reservoir length as well as the effect of mud rheology on flow development. Then, a parametric study of this model is produced and the effect of mud shear-thinning on flow development is pointed out.

Zusammenfassung:
Die Hauptmerkmale von geologischen Flüssen, wie beispielsweise Schuttlawinen, Lawinen und vulkanischen Schlammströmen (Lahars), hängen vom Verhältnis der Zähflüssigkeits und Trägheitskräfte in der Impulserhaltungsgleichung ab. Diese Arbeit beschäftigt sich mit den Bewegungen, die beim Bruch eines Dammes entstehen, der eine zähflüssige Substanz zurückhält, die durch eine Kraftgesetzflüssigkeit modelliert wird. Die Bewegungsgleichung wird in adimensionaler Form hergeleitet, und analytisch gelöst, unter der Seichtwasserhypothese für einem trockenen und glatten horizontalen Kanal. Insbesondere werden Wasserstandsverhältnisse und der Einfluss der Beckenlänge sowie der Einfluss der Rheologie der zähflüssigen Substanz auf die Flussentwicklung aufgezeigt. Danach wird eine Parameterstudie dieses Modelles angefertigt und der Effekt der Ausscherung der zähflüssigen Substanz auf die Flussenwicklung wird herausgearbeitet.

Résumé:
La principale caractéristique des écoulements géologiques tels que les laves torrentielles, les avalanches et les lahars est dûe à l'importance relative des forces de viscosité par rapport aux forces d'inertie dans l'équation de conservation de la quantité de mouvement. Le présent article s'intéresse au mouvement généré par la rupture d'un barrage retenant de la boue, celle-ci étant modélisée par un fluide à loi de puissance. L'équation du mouvement est formée sous forme adimensionnelle et résolue analytiquement avec l'hypothèse des eaux peu profondes dans un canal horizontal, lisse et sec à l'aval. Tout particulièrement, les régimes d'écoulement et l'effet de la longueur du réservoir ainsi que l'effet de la rhéologie de la boue sur le développement de l'écoulement sont étudiés. Par la suite, une étude paramétrique est réalisée et l'effet de la rhéofluidification de la boue sur le développement de l'écoulement est précisé.

Key words: dam failure; mudflow, debris flow, open channel, Power-law model, shallow-water

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5 CONCLUSION

The horizontal dam-break flow of mud modeled by a power-law fluid was considered analytically. The channel was smooth and dry at initial time. The solution of such problem depends on the time scale. The inertial regime characterized by dominant inertial forces, takes place immediately after dam collapse, and holds until the negative wave touches the rear wall. In such an inviscid solution (Ritter solution), the rheological behaviour of the mud has no influence. Then, the viscous forces become the dominant forces and a viscous solution is obtained. Applying the conservation of mass and momentum with the shallow water approximation, an equation of motion was derived and made non-dimensional. The analytical solution of this viscous flow was worked out in terms of wave front dynamics and spatio-temporal variations in the fluid height, with a self-similar form. The short time solution holds until the wave reflected by the (fixed) rear wall overtakes the front and then the long time one governs the asymptotical flow dynamics and shape. The limiting case of a Newtonian fluid derived from this solution was successfully compared with previous experimental, analytical and numerical solution. Then the shear thinning property of the mud was pointed out. Firstly, it was shown that the general features of the physical description of the development of the dam-break flows of both the water and the mud are similar. Moreover, all these results illustrate the increasing of the velocity of the negative wave and the positive wave with power law index, due to lower friction for the water than for the mud characterized by the same consistency. For all the tested values of the power law index ($0.2 \leq n \leq 1$), the maximum heights at given station versus the corresponding abscissa were described by a single graph. Finally, it was shown that for a structure situated in a vulnerable zone, the impact will occur later for the mud than for the water but the quantity of fluid will be larger, and considering that the density of the mud is larger than that of the water, the impact of the mud is expected to be greater and potentially produce more damages.

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