Renewable Energy and Power Quality Journal (RE&PQJ), ISSN 2172-038 X, No.9, 12th May 2011, Reference Paper: 662

European Association for the Development of Renewable Energies, Environment and Power Quality (EA4EPQ)

International Conference on Renewable Energies and Power Quality (ICREPQ'11)
Las Palmas de Gran Canaria (Spain), 13th to 15th April, 2011

Equipment Safety in Renewable Energies Exploitation

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Abstract: This paper considers the dam-break problem in a horizontal smooth 1D channel, for the purpose of equipment safety in renewable energies exploitation. The fluid is water and it can be described by a Newtonian model, provided that the inertial effects be neglected versus the viscous ones in the momentum balance. Assuming the shallow water approximation, a non dimensional equation is built from the continuity and the Navier-Stokes equations in the limit of zero-inertia and it is solved analytically in two limits: short time and long time. These solutions are then combined into a single, universal model. Limitations of the model are examined by comparison to a converged finite difference numerical solution of the flow equation.

Key words

Dam failure, Finite difference method, Flow regimes, Shallow water approximation, Similar solution.

1. Introduction

Nowadays, Hydraulics which represents 90% of the sources of renewable energies used for producing electricity in the world is in progress mostly in the developing countries. Hydraulics is the only renewable energy which allows to make a stock of energy. Owing to the huge quantities of water retained behind dams, genuine energy reservoirs are available and ready to produce electricity at request. The bigger the dam is, the greater the pressure at its bottom is. Due to the system malfunction or an act of war (e.g. Dnieproghes, Ukraine in 1941), the dam can collapse. The water released downstream can destroy fields, goods, infrastructure and kill people and animals.

Since Ritter's original work on dam-break flow [1], many studies have been performed focusing on experiments, theory and numerical methods [2]. Dam-break flow has become a classical hydraulic problem with such a large complexity that a higher degree of reproduction of real conditions raises new studies. Consider a dam obstructing a horizontal smooth channel, dry downstream and with a given quantity of fluid upstream (with height h_0), contained between a fix plate and a dam. At initial time, the dam collapses and the fluid is released downstream (positive wave), while a negative wave propagates upstream (negative wave). From dam-collapse date to time where negative wave reaches the fix plate, Ritter [1] gives the so-called inertial solution, stating that the wave front advances with a constant speed of $2\sqrt{gh_0}$, while the negative wave moves back with constant speed $\sqrt{gh_0}$. The fluid is water and the flow is described by the Navier Stokes and continuity equations, together with the non slip condition. Assuming the shallow water approximation, this system of equations leads to the Saint-Venant equations [3], a one-dimensional hyperbolic system. The complete hydrodynamic equations describing this unsteady flow in open channel were solved by Faure and Nahas [4], using the method of characteristics. Hunt [5], comparing one-dimensional turbulent flow model down a slope with its viscous counterpart, concluded that the viscous flow model gives the best description for debris flows. Indeed, these flows develop within a long domain, i.e. a domain of space that is much longer than it is wide, so short time behavior described by the previous studies are inappropriate to give a complete description of these natural flows. Natural flows generally erode their bed and transport sediments. For image analysis purpose, experimentalists generally slow down the flow by using viscous complex mixtures of water with diverse additive. Nsom et al.[6] and Nsom [7] performed an experimental study with glucose-syrup fluids characterized with adjustable viscosity and density. Hunt [5] built similarity solutions for such "geological flows" down a sloping 1D channel. Also, Schwarz [8] achieved a numerical study of viscous thin liquid films down an inclined plane. Solving free surface lubrication equations, including the effects of