PFEM APPLICATIONS IN DAM ENGINEERING

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Abstract. *The paper presents some applications of the Particle Finite Element Method (PFEM) for solving advanced fluid-structure-interaction problems in the field of dam engineering. Results of the analysis of landslides in reservoirs are presented, in which the whole process is simulated: the initiation of the instability, the formation of the wave in the reservoir, its propagation, and the affection to the dam. Additional examples related to the assessment of the behaviour of spillways, both chutes and energy dissipators, are described, taking into account the effect of the erosion in the downstream river bed. Finally, our experience in the use of GiD for pre and postprocess of this kind of calculations is summarized.*

1 INTRODUCTION

The Particle Finite Element Method (PFEM) is a particular class of Lagrangian formulation aiming to solve problems involving the interaction between fluids and solids in a unified manner [1], [2]. Being developed in CIMNE during the major part of its life, PFEM's natural evolution has been linked to GiD, and even to GiD's own evolution [1]. PFEM features have been described in previous GiD conferences, so this paper won't focus in this issue. For further information, references [2], [3], and [4] can be consulted.

Our work focuses on the application of this numerical code to the resolution of engineering problems related to dam engineering, such as spillways, outlets and landslides in reservoirs.

2 SPILLWAYS

2. 1 3D analysis

In figure 1 a 3D case of a spillway is presented. The most important issue in this particular case is the analysis of the flow in the chute, considering that it has converging walls. This feature provokes the formation of shock waves that in some cases may cause high water depths. This test case is based in the geometry of an actual dam, as well as in the final report of the physical model tests carried out before its construction.

During the physical tests on the original geometry, the formation of shock waves next to the walls was observed. These shock waves met at the entrance of the energy dissipator, causing high flow velocities, and non desirable behavior of the structure. Besides, a little portion of the flow jumped over the walls. After some modifications on the shape of the walls, the shock waves couldn't be eliminated, but a better distribution of the flow was achieved, and the energy dissipation was improved. The numerical model reproduced the mentioned effects both in the original and in the final geometries, as can be seen in Figure 2.

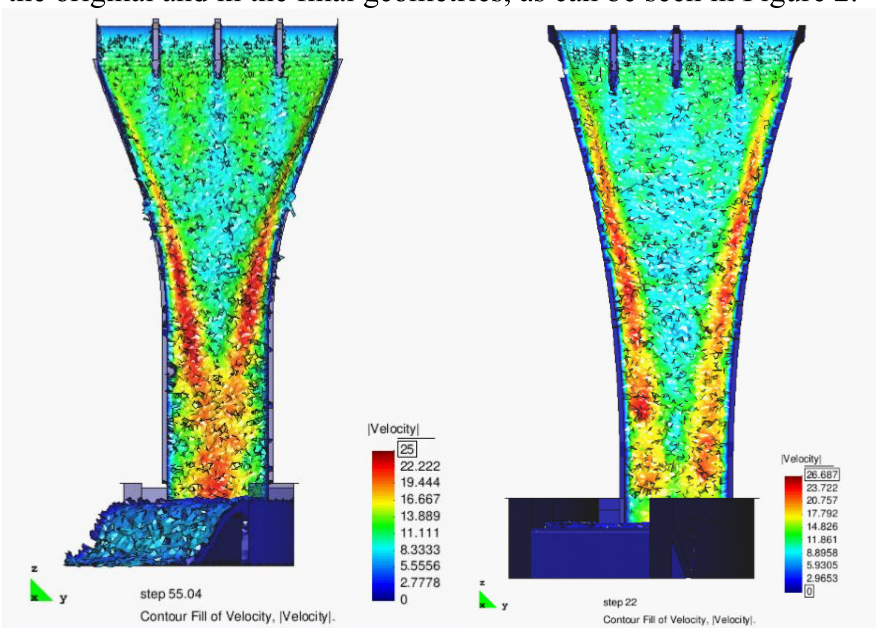

Figure 1. Snapshots of the calculation of a converging spillway. Geometries proposed in the project (left), and finally constructed (right).

2.1 Erosion

PFEM has been developed so that it can simulate the erosion of the river bed due to the effect of water [5]. Figure 2 shows an example of the application of this capability to the study of the behavior of a sky jump spillway. The objective of this typology is to throw the water far from the downstream toe to avoid backward erosion that may cause the instability of the dam.

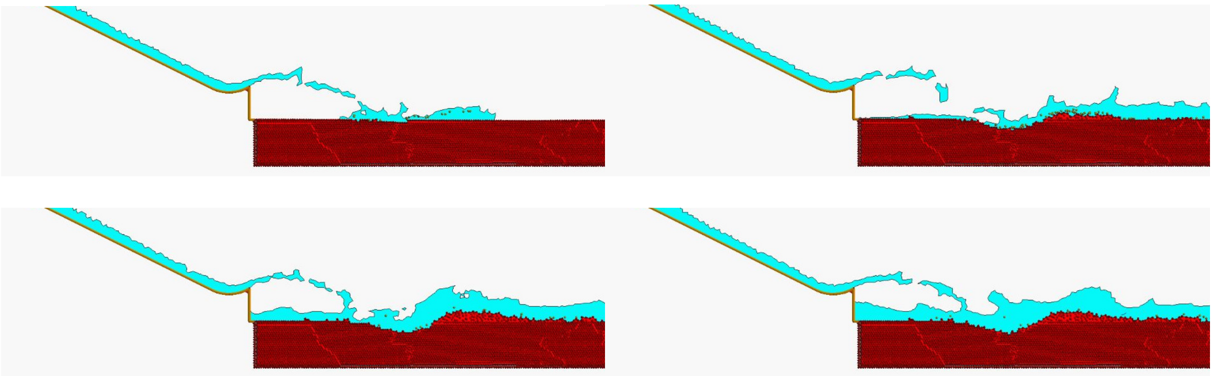

Figure 2. Simulation of erosion downstream a sky jump spillway

3 LANDSLIDES IN RESERVOIRS

PFEM is being applied to more complex cases, such as the analysis of the propagation of landslides in reservoirs. This phenomenon includes different mechanisms: a) the propagation of the landslide, b) the formation of the wave due to the interaction with the water in the reservoir, c) the propagation of this wave in the reservoir, and d) the run up over the dam or the opposite margin. In this kind of calculations, there is a great uncertainty in some of the variables involved, such as the volume of the landslide and the nature of its motion (whether it moves like a solid, or like a dense fluid). Different physical experiments have been carried out all over the world to understand the phenomenon. In our work, we have reproduced some of these physical tests, to validate the results, before running more complex examples in 3D. Figure 3 shows some snapshots of one of the tests run, where a hypothetical landslide has been studied using the actual topography of a Spanish reservoir.

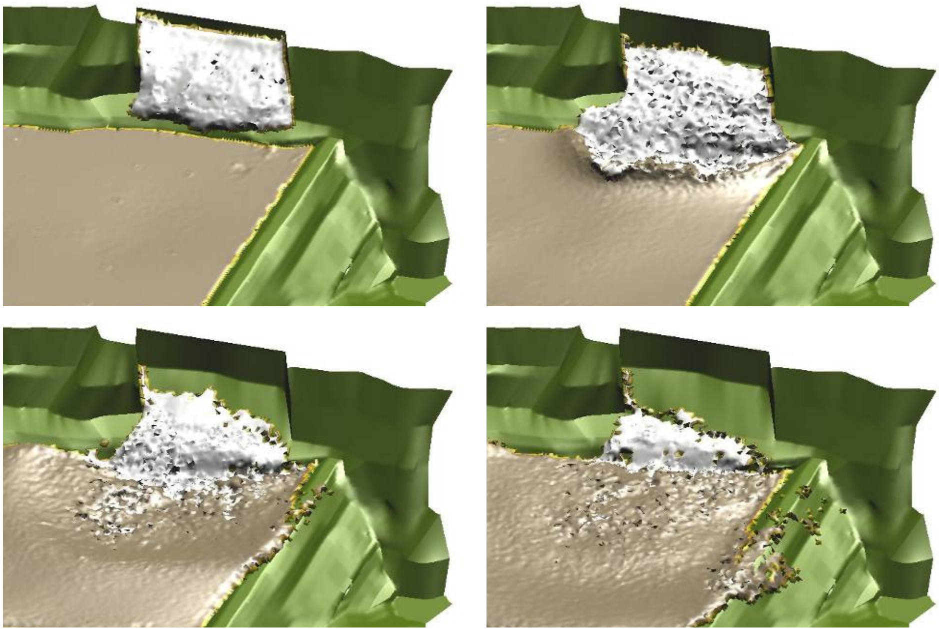

Figure 3. Landslide, wave generation, and dam overtopping (right)

4 GID CAPABILITIES FOR PFEM PROBLEMS

As far as our work is concerned, we have found two main difficulties regarding pre and postprocess. For the cases in which the geometry is well defined by plans, (i. e. concrete structures, such as spillways), preprocess is simple, because GiD has all the tools needed for 3D design, as well as for the efficient generation of the initial mesh. The main problem in these cases concerns postprocess, and relies in the fact that one of the most important results we are searching is the discharge in different sections of the model. Before the last GiD version (9.2.7.), there were not a simple way to graph it, and it had to be obtained by means of laborious procedures. Fortunately, the mentioned version of GiD includes a new tool that graphs the integral of a variable over a mesh. This new feature has increased the applicability of PFEM to hydraulic calculations.

The second problem we have found regards preprocess, and corresponds to the steps needed for the transformation of topographic information, available in different formats, into a finite element mesh. Topography is usually found in some of the formats used by GIS, such as *shp*, *lyr*, *raster*, etc. GiD allows the user to import *shp* files, as well as text files with points coordinates or *dxf* files. These options are very useful. A NURBS surface has to be generated next (topographic information consists usually in contour lines, or points), which can be done in GiD by points, by parallel lines, or by line points. These tools work very efficiently, even for large surfaces. We have got better results using points, although the starting information consisted of contour lines.

5 CONCLUSIONS

PFEM and GiD continue the parallel development that has been followed in the last years. The application of PFEM to more complex problems requires the creation of new GiD tools both for preprocess, which has to be adapted to work with different formats and postprocess, where new ways for presenting results are needed and different variables are searched for. So far the response of GiD has been quick and satisfactory for PFEM users, so our perspective is optimistic for the next years.

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