Introduction

A seismic event is associated with the propagation in the space and in time of a rupture, which originates in a region that is no able to substain (by accomodating as plastic deformations) the tectonic load that solicitates it. Such a propagation of seismic waves is perceived as tremors and it represents the smallest part of energy released during the process, mainly dissipated as frictional heat within the surfaces in contact and as energy used to increase the rupture itself.

We are also able to analytically represent a rupture. The experimental studies of materials have shown the fundamentals properties of brittle and plastic regimes and we refer to a rupture as an analytical deviation from the linear, elastic Hooke' s law.

From this schematic picture one can imagine that the Gilbert' s aim can be eventually satisfied, that is that " now that it too has passed from the shadow of the occult to the light of knowledge, the people of civilized earth — the lay client of the seismologist — would be glad to know whether the time has yet come for a scientific forecast of impending tremors. " But, unfortunately, it is not the case. We don' t know exactly the state of the stress and in general the initial conditions on a fault; moreover we don' t know the precise geometry of the faults. We don' t know what physical laws are able do correctly describe the processes of the nucleation, dynamic propagation, arrest and healing phenomena, stress interactions and triggering between different faults or segments.

Over three recent decades laboratory experiments and observations of real – world seismic events provided us a very sophisticated framework of constitutive models or governing equations. The theoretical modelling in source dynamic is a way to show what are the prominent features of a governing law, what kind of physical processes it is able to describe and if such a description is compatible with a specific observed phenomenon. The continuous feed back between laboratory data, real events observations and numerical, synthetic results can increase our degree of knowledge about the physical laws describing the seismic processes.

The goal of this Ph.D. Thesis is to show and discuss implications of the main aspects of different governing laws in the description of all phases of seismogenic processes: nucleation, dynamic propagation and energy release, healing, arrest and mutual interactions between faults. This has been done by implementing or developing numerical codes and algorithms able to solve, in various dimensionalities, the fully dynamic, spontaneous problem.

The next stage of the research project in which this work is inserted is to try to infer some constitutive details from real events, in order to discriminate between different models.

In the Chapter 1 we present the state of the art in source dynamics, describing the fundamentals of coseismic processes, dynamic problem and fracture energy and constitutive models. This work is focused on two different class of governing equations: the first class is represented mainly by the slip – weakening law, introduced by Ida (1972) and based on the concept of cohesive zone previously proposed by Barenblatt (1959a, 1959b). The second class is populated by the rate – and state – dependent friction laws, originally based on stick – slip laboratory experiments made by Dieterich and coworkers at USGS in Menlo Park, California.

The motivation of Chapter 2 is to introduce the numerical methods that I developed in the recent four years in order to solve the dynamic problem. We present the result arising from the comparison between different numerical codes (Boundary Integral Equation, BIE and Finite Differences, FD) and between various constitutive laws. We are mainly interested in this Chapter in the study of the dynamic propagation and on the implications the processes accomplished within the cohesive zone. We propose some correspondency relations between different constitutive parameters. A detailed comparison between the description of the nucleation stage is also discussed.

Chapter 3 is oriented to generalize the results presented in the previous Chapter to a more realistic configurations in which spatial heterogeneities take place. We discuss the healing phenomenon and the physical processes that lead to crack arrest. This Chapter present situations that are directly linked with the real world events, even in the approximation of a 2 – D in – plane fault, i. e, a fault in which all the solutions of the dynamic problem depend only on one spatial coordinate and on the time.

The Chapter 4 present the more general configurations, that is a 3 – D fault, in which all the solutions are dependent on two spatial coordinates and on the time. We present in that Chapter the Finite Difference numerical code and we discuss both the fault boundary condition and the domain boundary conditions. Some results are presented starting with the classical slip – weakening law, emphasizing the importance of the rake variations during propagation. To complete the exposition we conclude the Chapter presenting some results obtained for heterogeneous configuration, that can be regarded as end members for the simulation of a real seismic event.

Chapter 5, the Part II of the Ph.D. Thesis, is focused on the stress interactions and fault triggering phenomena. Because of the complexity of these processes and the too challenging computational resources required for the simulation of the whole seismic cycle, we study the problem by using a simple spring – slider model with only one degree of freedom (i. e. a 1 – D fault in our naming conventions). We analyze the differences existing between static, permanent stress perturbations and dynamic, pulse like stress perturbations. We stress the importance of the role of the initial conditions of the system, i. e. the fault state at the application of the stress perturbations arising from neighbouring faults.

We insert in the Appendixes some analytical details, and what is more, an accurate analysis of the convergence conditions. We discuss all the requested conditions for all algorithms presented in this work. We believe that is not only a technical aspect of our results, because we have to have a tool to evaluate if our results are properly correct or simply polluted by artificial numerical problems.

This Ph.D. Thesis is based on some papers that have been recently published: Belardinelli et al. (2003), Bizzarri et al. (2001), Bizzarri and Cocco (2003), Cocco and Bizzarri (2002), Cocco et al. (2003). Readers can refer to these papers for a more detailed description of some technical aspects and deep numerical discussions.