A thesis presented to

THE GRADUATE SCHOOL OF SCIENCE

KYOTO UNIVERSITY

By

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In Partial Fulfillment of the Requirement of the Degree

DOCTOR OF SCIENCE

(Geophysical Sciences)

A Full Dynamic Shear and Tensile Crack Propagation during an Earthquake using a 3D Discrete Element Method

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Kyoto, March of 2002

SUMMARY

Dynamic simulation of rupture process is usually performed under the assumption in which only shear slip (Mode II and/or III) occurs during an earthquake, this is widely accepted in the study of earthquakes because this phenomenon may be considered to be a dynamically running shear crack. But it is very well know that the rupture process of an earthquake is a fracture dynamic problem, therefore, the superposition of the three basic modes (Mode I, II and III) is sufficient to describe the most general case of the dynamic crack propagation.

In this context, in the present thesis, a 3D numerical simulation of the dynamic rupture process of an earthquake involving the three basic modes is performed. We assume that the shear slip takes place only in a pre-existing fault and the tensile cracks propagate as a consequence of the dynamic process of the shear slip propagation. For this purpose we use the Discrete Element Method (DEM). This numerical technique consists in the representation of solids modeled by an array of normal and diagonal elements linking lumped nodal masses. The dynamic process is obtained by resolving the simple equation of motion of Newton law for each lumped nodal mass by an explicit numerical integration in the time domain. The numerical solution is developed for near-field elastodynamic motion coupled to frictional sliding on a pre-existing fault. For the spontaneous shear rupture propagation the simple slip weakening model is used as a friction law on the pre-existing fault, and for the new tensile cracks, the fracture will occur, following the classical Griffith theory, when the critical value of tensile fracture surface energy has been reached.

The spontaneous shear rupture and tensile cracks propagation is simulated for a theoretical vertical strike slip fault (19km x 19km) with an asperity (7km x 7km). The fault is embedded at a depth of 3km from the free-surface. The results suggest that the new cracks generated by the shear slipping extend mainly from the borders of the pre-existing fault and asperity forming a flower structure. The variation of the asperity location with depth strongly affects the cracks generated from the top of the fault and the free-surface rupture. It was also found that the generation of tensile cracks strongly affects the rupture process of the fault and the near source ground motion. The pattern of the ground motion suffers a drastic change.

Finally, the model is used to simulate the full dynamic rupture process and the ground motion of the 2000 Tottori earthquake. The results show that the new tensile cracks reach the free-surface and grew from the two side of the fault following different patterns and forming new fractures as a complex flower structure. The trace of the surface rupture is consistent with the cracks found on the field observation. Some of the new cracks correspond to the zone of after shocks distribution, suggesting that the cracks opened during the shear rupture could be the zone of potential aftershocks. It was also observed that the generation of tensile cracks predicts ground motions with higher frequency content than a model free of cracks. The simulated ground motion shows that the main features of the recorded ground motion can be reproduced. These results imply that the formulation presented in the present thesis could be used successfully in predicting near source ground motion, fracture behaviour during an earthquake and the formation of new fault zones.

ACKNOWLEDGEMENTS

I am very thankful to Prof. Kojiro Irikura, my advisor, for his valuable and wise advise during these three years and I appreciate his patience and understanding; thanks to his wisdom he had the enough knowledge to overcome all the problems related to the difference of language and culture, "DOMO ARIGATOO PROFESSOR IRIKURA!!".

I am also very thankful to Prof. Jorge Daniel Riera, from the Federal University of Rio Grande do Sul, Brazil, for his permanent and always important suggestions and recommendations and discussions that we use to have through the e-mail about my study and related fields.

To my colleagues Haruko Sekiguchi, in the time when she was member of our laboratory, to Hiroe Miyake and Cesar Moya for their patience when dealing with computers and to Nelson Pulido, Anatoly Petukhin, Wenbo Zhang and Gulum Birgoren, all of them, for their friendship.

To Dr. Iwata for providing space and facilities for use the computer of his own project.

To my friends for their help and precious friendship. These friends, that I prefere keep as anonymous because they know who I am talking about, made my life in Japan more confortable and more happy.

A special thank to Haru Pienek.

To my family, to whom I dedicate this thesis, overcoming the distance, they always gave me the enough support to me make reality one of my objective.

My gratitude to the Ministry of Education, Science, Sports and Culture of Japan for supporting my study in Japan.

I apologize to everyone because I become painfully aware of my limited experience and knowledge in the broad field of seismology and related fields.

Finally, I would like to thank to God, because without him, nothing would be possible.

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