Microcrack propagation in rock specimens and its effect on mechanical properties

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1 INTRODUCTION

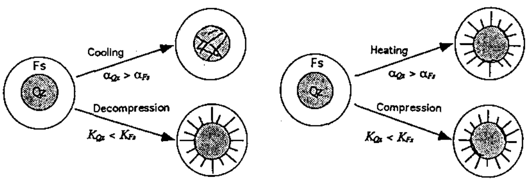
Crystalline rocks, granitic rocks, commonly display complex composite microcrack system which have found progressively by different geologic processes and under varing conditions. Mechanical properties of these rocks or rock masses are affected strongly by microcracks. Therefore, microcracking such as intracrystalline-, intercrystalline-, cleavage-, and grain boundary microcracking connected with grains(minerals) included in rocks very important to study a " true " damaging induced by microcracking in rocks and rock masses.

Many researchers, experimentally, have undertaken the laborious task of loading samples to different stages of deformation and then counting microcrack damage in thin section or using SEM techniques and AE events. Whereas, the details of how microcracks nucleate, grow and coalescence, and its relation to mechanical properties, and especially that of transition from micro- to macro- have remained an enigma for so long.

In this paper, we applied to clarify a " true " damage propagation(from micro- to macro-) in granite and its effect to mechanical properties from the experimental system developed newly and homogenization method.

2 BISPHERE MODEL IN GRANITE

Granite used in the present study may be described in simplified terms as a two component system(bisphere) consisting of quartz and feldspar because the number and size of biotite are not large enough to be compared to those of other minerals.



a) Geological history b) External stresses

Fig. 1. Microcracking in quartz-feldspar(bisphere).

2.1 Microcracking caused by geological history

Nur and Simmons(1970) reported that quartz grain in granite underwent a large volume change upon cooling from 600°C; about 4 - 5 percent compared to a value of 1 - 2 percent for most other common silicate minerals. That is, quartz grain undergoes a greater contraction than the feldspar leading to high tensile stresses in the quartz. It is also one of the most compressible silicates. Therefore, the existence of these pre-existing microcracks is due mainly to the differential thermo-mechanical properties of minerals and in particular quartz in these rocks. Fig.1a) schematically explains the initiation of pre-existing microcracks within such a quartz-feldspar grain(bisphere) model when subjected to changing temperature or stress during geologic history. It follows from the corresponding volumetric strains that the stranger elastic sxpansion of quartz during decompression favours microcracking in the feldspar grain while the stronger thermal contraction of quartz grain during cooling leads to microcracking in the quartz grain.

Many pre-existing intracrystalline microcracks in quartz were mainly induced by internal thermal stress variations. Therefore, intracrystalline microcracks in quartz grain are due to not only to external deviatoric stresses, but also to internal stresses on the grain scale resulting from the strong thermal contraction of quartz relative to the feldspar framework. In quartz grain contained in granite specimens used the present experiments, healed pre-existing intracrystalline microcracks are well developed in various direction, whereas those in feldspar grains were few.

2.2 Microcracking under external stresses

Geometry of healed pre-existing grain boundary microcrack consisted of many microcavities between grains is important in controlling the initiation and growth of stress-induced microcracks, that is, intracrystalline microcracks of tensile state play an important role on the formation of fracture and subsequent failure.

In quartz-feldspar bisphere, as compared to feldspar, quartz is characterized by a significantly high values of compressibility.

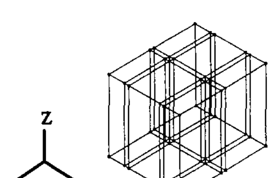


Fig. 2. Mesh for mechanical property of quartz including healed pre-existing microcracks.

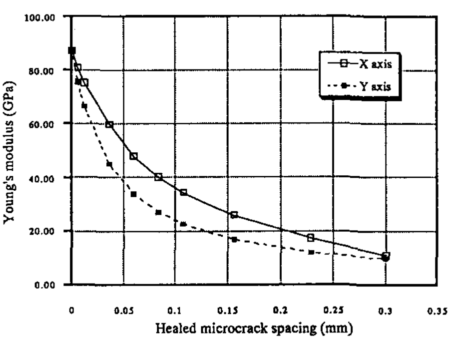


Fig. 3. Graph showing the decreasing of Young's modulus with increasing of healed microcrack spacing in quartz by homogenization method.

Fig.1b) schematically illustrates the initiation of microcracking within such a quartz-feldspar bisphere when subjected to changing stress. Stress-induced intracrystalline microcracks in feldspar grain is initiated at healed pre-existing grain boundary microcracks of interlocked state, at a stress 30 MPa, extended nearly parallel to the axial stress direction.

3 MICROCRACK PROPAGATION AND MECHANICAL BEHAVIOR

Understanding on the interaction between minerals under stress furnishes detailed evidence on damaging process of inhomogeneous rocks. Therefore, this interaction in the form of microcracks may profoundly influence mechanical properties of rocks. First mechanical properties of quartz including healed pre-existing microcracks must be computed to determine that of quartz-feldspar bisphere. Fig.2 is mesh of unit cell in quartz grain including healed pre-existing microcracks. Variation of Young's modulus of quartz grain with opening of healed pre-existing microcracks is nonlinear(Fig.3).

The location of stress-induced microcrack initiation, growth directions and distribution of these microcracks, and the relation between healed pre-existing microcracks and stress-induced microcracks were observed in great detail with the use of the stereoscopic microscope during loading. In bisphere model, relation between the microcrack spacing and length in feldspar and microcrack spacing in quartz from experiments shows in Fig.4.

Fig.6 illustrates increasing of Young's modulus decrement with increasing of volume fraction of microcrack in feldspar and anisotropy computed from bisphere mesh(Fig.5). Decreasing of normalized Young's modulus with increasing of volume fraction of microcrack in feldspar grain is illustrated in Fig.7 , which is nonlinear that normalized Young's modulus drops fast as soon as stress-induced microcracks initiate.

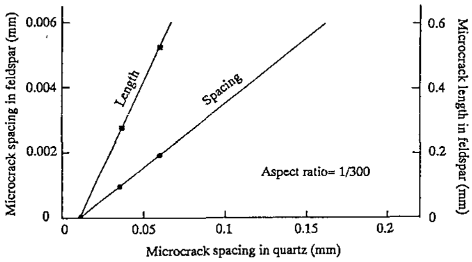


Fig. 4. Graph showing relation between microcrack spacing and length in feldspar and microcrack spacing in quartz.

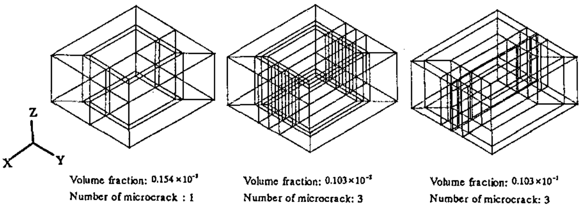


Fig. 5. Mesh for the microcrack propagation in bisphere model.

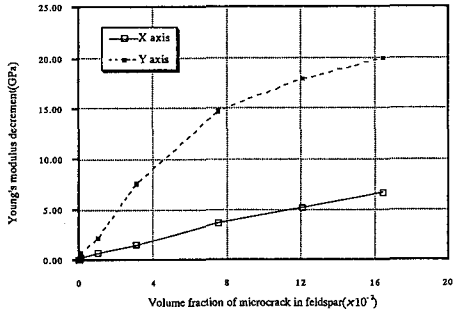


Fig. 6. Graph showing increasing of Young's modulus decrement with increasing of volume fraction of microcrack in feldspar.

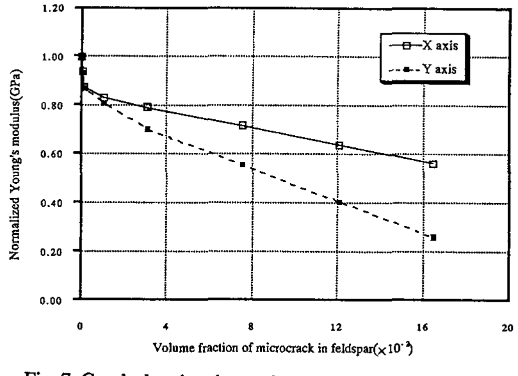


Fig. 7. Graph showing decreasing of normalized Young's modulus with increasing of volume fraction of microcrack in feldspar.

4 CONCLUSIONS

This study is limited only to the interaction of two minerals such as quartz and feldspar grain for grain scale microcrack initiation and growth from not artificial pre-existing crack state but natural pre-existing microcrack state, and since granite used the present study can be described in simplified terms as a two component system consisting of quartz and feldspar, which is the basis of understanding the multiple-grain interaction in crystalline rocks. We are now implementing the present model into the macro-analysis in homogenization method.

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