Abstract

Identification of pre-failure indicator of structures made in rock mass is of immense importance to mining, civil and geo-technical engineers for ensuing stability. Over the years many contact based sensor techniques have been tried with limited success. The objective of this research work is to develop a non-contact based system for monitoring geomaterials failure mechanism and more importantly to generate a prefailure indicator during loading process.

Multilevel finite element based digital image correlation (FEM-DIC) method is found to be a better alternative in digital image correlation (DIC) technique and produces one order less error as compare to existing Subset-DIC method. An indigenous multichannel data acquisition system is developed in the laboratory for capturing images and other data synchronously during the experiment. The developed system is further used to check the performance of the proposed multilevel FEM-DIC method in experimental domain by applying a cyclic loading on the samples. It is found that it is possible to monitor the deformation of rock sample at every locations with time in a non-contact manner and shows promise to expand its application into rock failure phenomena. FEM-DIC method is further refined and developed multilevel extended digital image correlation (X-DIC) technique for monitoring deformation of samples having discontinuities. The performance of X-DIC technique is checked by conducting numerical examples where typical known deformation patterns are applied as in deformed image. The maximum MSE is found to be in the order of 10^{-5}. The thesis develops a method for generating speckle patterns on the surface of experimental samples which is helpful for conducting repetitive experiments. Multilevel X-DIC technique is then applied for distinguishing displacement pattern of non-fractured zone from those of fractured zone of a sample based on the displacement jumps. The concept of Smooth Particle Hydrodynamics(SPH) is also introduced to estimate strain tensors at nodes. The proposed method is found to be useful to reduce the noise level (if presents) in the computed displacements by conducting both numerical and experimental studies. An automatic damage zone(s) detection and classification algorithm is developed for extracting the damage information in automatic way. It is found that, this proposed algorithm can be added on top of FEM-DIC technique to measure high precision deformation/strain considering damaged conditions.

Finally, the research work is focused on the final objective of this research work. Cumulative effective strain data are used to generate pre-failure indicator (yielding point) of material during loading process. A new algorithm is developed to generate pre-failure indicator during material failure process. It is found that, ratio of slopes $(\frac{\alpha_2}{\alpha_1}) \geq 1.8$ is a clear indication that the material departs from elastic region and enter into yielding region. Using this concept, yielding of any structure may be ascertained in a non-contact manner and shows a tremendous potential for field applications. This threshold value also turns out to be an indicator of 75% of peak stress in the samples which is normally considered as yield point.

Keywords: Geomaterials failure; DIC; FEM-DIC; X-DIC; Non-contact monitoring; SPH; Prefailure indicator; Damage detection and classification