A Study of Rock Cutting by Diamond Wire Saw Blade

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Abstract

The process of rock cutting by diamond material is simulated with using analysis of LS-DYNA finite element. This paper presents a study for excavation of the rock utilizing diamond wire cutting tools. The greatest benefit of the diamond wire cutting is the vibration free extraction of rock. Compared to the conventional technology, this technology produce much faster cutting, less noise and easy installation. When the diamond particle is in contact with the base rock, the cutting force raises gradually. The diamond material is mounted on a steel body which is called beads, diamond materials are chemically attached with the surface of the beads. In this study, the base rock material is considered as a damage constitutive model. It is demonstrated in this paper that, by analysing the stress, strain and cutting force, one can measure the cutting depth in per rotation. In future research it could possible to analyse the diamond shape and arrangement on the bead to find out more efficient and time consumable rock cutting process.

Keywords: Rock cutting, Diamond wire saw, LS-Dyna

1. Introduction

Different engineering applications including mining, tunnelling, etc. uses mechanical rock cutting process. Rock cutting is the principle work performed for the tunnelling. Various types of rock cutting process are performed this days (i.e., sawing, rotary blade, drilling etc.) Diamond wire saw have played an important role in recent decades, to perform the cutting process of rock. Diamond wire saw cutting process is widely used for rock excavation because of their high flexibility, high production rate, low noise level, low cost and high energy efficiency, particularly when compared to circular saws.

In the process of rock cutting with diamond wire, beads are the most important part of this tool. Because beads are the responsible for the cutting of the rock particles. And diamond particles are place in the surface of the beads steel body[3]. When this diamonds come contact with the rock surface with certain velocity, rock particles removes from the workpiece. It is really time consuming and costly to find out the efficient cutting process with diamond material in the lab experiment. Thus, numerical simulation is one of the best solution to find out the nearest possible result which can useful in the real situation.

In this paper the process of whole cutting process have been simulated with LS-DYNA finite element method. With the recent development of computer technology, FEM method in cutting process is most commonly used. There are basically two kind of methods for FEM process, that is Lagrange method and the Euler method.

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Lagrange method is used for solid structure of stress strain analysis, Euler method is used for fluid analysis. In this paper Lagrange method is adopted for stress strain analysis after the cutting process of the workpiece. The result provides the theoretical methods of the diamond wire sawing for the rock cutting.

2. Numerical Simulation Part Details

All the simulation were performed in this paper with an explicit non-linear finite element code, LS-DYNA. In this simulation, a cutting tool and a base rock were considered for modelling. The base rock was modelled as a rectangular block of 100 mm in length and 7.5 mm in height. 2D quadrilateral shell elements were used for both the cutter tool and the base rock. To prevent the base rock lower and side part movement (as the cutting force applied in the top part of the rock surface), boundary conditions have been applied. Displacement boundary conditions were, fully constrained in X-, Y- and Z-direction on the bottom and side of the base rock. The cutter was constrained in the Z-direction. For making contact with the cutter and the base rock, approximately 1 N load were applied from the top of the cutter. And 20 m/s velocity have been given towards X-direction, thus the cutter move and cut the top surface of the base rock. The cutter has been modelled as a rigid body and the base rock as a deformable body. For the rigid body, material type, 20_Rigid was assigned to the cutter and material type 105_Damage_2 was assigned to the base rock model.

a) Bead b) Base Rock

Fig. 1 Model Parts

For the material properties, steel and rock material were assigned to the bead and base rock respectively. Material properties for the base rocks were, the density, ρ, of 2,400 kg/m^3, Young's modulus, E, of 15.7 GPa and a Poisson's ratio, v, of 0.11. The cutter and the base rock contacts were simulated using automatic surface to surface contact.

3. Result and Discussion

During the analysing process, it could be observed the deformation of the base rock surface due to the contact with the rigid cutter node. When the rigid cutter part make contact with the rock surface, a high fluctuation of the internal energy has been occurred. This energy fluctuation occurred due to the stress distribution which is shown in the figure- 2. The simulation result is in the figure-3. The displacement of the rock surface also fluctuate due to the contact. The graph can observed from figure-4

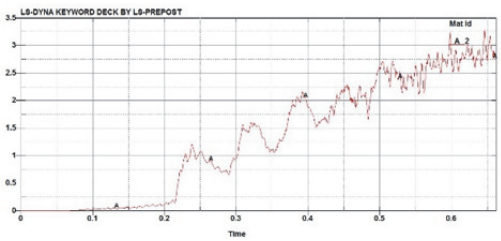

Figure-2: Total Energy

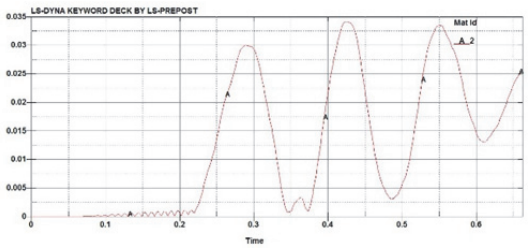

Figure-4: Displacement

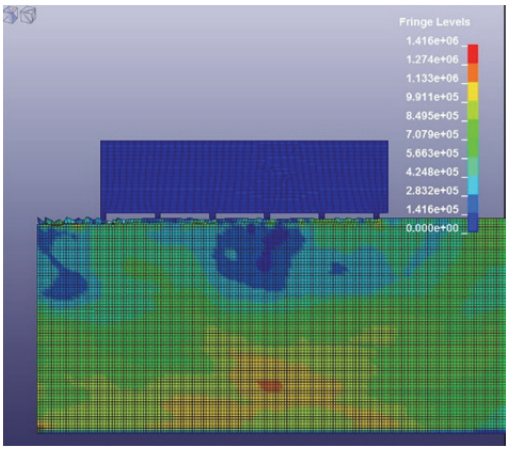

Figure-3: Rock surface deformation

4. Conclusion and Future Research

In this paper, a simulation has been shown by LS-DYNA, which could use as a future reference of the study on rock cutting. The cutting force and the behaviour of rock during the cutting process can be observe from this simulation.
Although a two-dimensional simulation was performed, in future research, a three-dimensional simulation can be established with LS-DYNA. Thus, the performance of the diamond with the rock surface can be observe easily. Also with per rotation of the bead, the depth of the cutting on the base rock surface can be calculate. The position of the diamond on the bead surface also can measure with the three-dimensional simulation.

5. Reference

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