2015 년도 한국철도학회 춘계학술대회 논문집 KSR2015S238

Analysis of Rock Cutting Simulation Using Finite Element Method

Mohammed Ruhul Kabir*, 사공명*†, 안성권**

Mohammed Ruhul Kabir*, Myung Sagong*†, Sung Kwon Ahn**

Abstract Rock excavation technology is one of the main focus in the tunnel engineering. Tunnel is an important structure in modern days, as the reason of urbanization many infrastructure are constructing on the underground. Where tunnels plays an important role with subway tunnels, highway tunnels, railway tunnels etc. In this paper a 2D model has been adopted to analyze the rock cutting procedure with a cutter and a rock surface. Stress and strain has also been analyze to compare the cutting force with different strength of rock surface. Numerical simulation is the easiest way to compare the various states of rock cutting compare to the field test. This simulation result could compare with the field experiment to corroborate the statement.

***Keywords* :** Diamond Wire Saw, Rock, Cutting, LS-DYNA

1. Introduction

Mechanical rock cutting is widely known in various engineering applications including mining, rock slab and so on. Drilling and cutting rock is one of the most important part in the construction site. For making various types of tunnels like road tunnel, railway tunnel etc. cutting rock is one of the principle work. Various kinds of research going on regarding this rock cutting and drilling. Still many improvement coming out for performing this important step.

To improve the cutting process, two types of research approaches usually made by researcher. Frist is doing the numerical simulation of the cutting process and then the physical testing. Using numerical simulation has been helpful to test the procedure in various conditions of rock or conditions. On the other hand physical test could support the numerical simulation results. In this study a rock cutting process has been simulated with a Finite Element Method by using LS-DYNA software. Among the simulation parts, there are two parts has been used in this study. One is the rock part and another is the rock surface. The cutter part is represents the diamond beads on the diamond wire saw machine. This study shows the cutting process by the bead and provides some reference values which could compare with the field experiment to improve the cutting process.

The diamond bead is the most important part in diamond wire saw. This beads will make contact with the rock surface and go through with the cutting process. Here wire velocity and wire tension plays an important role. In this simulation, velocity and normal force on the cutter has been given to make contact with the rock surface and proceed with the cutting process

† 교신저자: 한국철도기술연구원, 기획홍보실 (rockcore@krri.re.kr)
* UST, Railway System Engineering (sharif@krri.re.kr)
** 한국철도기술연구원, 융합신기술연구팀

2. Numerical 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 900 N load were applied from the top of the cutter and 25 mm/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.
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, ν, of 0.11. The cutter and the base rock contacts were simulated using automatic node to surface contact.

3. Result

Through the analysis we calculated the impact of the cutter on the rock surface and observed the cutting process. Figure 3 shows the initial position of the cutter and the rock surface. As instead before, approximately 900N load has been applied on the cutter towards the negative Y-direction. Thus the cutter could make contact with the rock

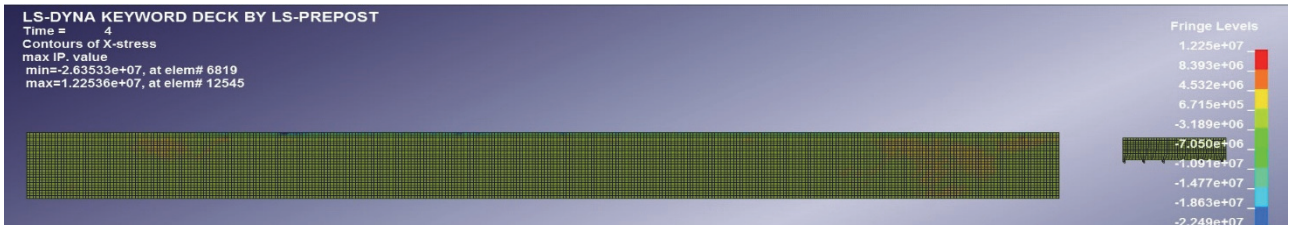

Fig. 1 After the First Rotation of the Bead

surface. A velocity has been given to the cutter towards X-direction which is 25mm/s (Figure 3), thus cutter could travel the whole rock surface. We could observe the result of the first analysis from figure 1. In this step the cutter made some contact on the rock surface. As instead before a velocity has been given to the cutter towards X-direction, throughout the analysis, the velocity change a little. Figure 3 shows the changed velocity of the bead.

After first analysis, the rock surface node has some little displacement. Thus the bead travelled the rock surface couples of time get the desired cutting on the rock surface. Figure 2 shows the final cutting on the rock surface, which we get after the 7 time rotation of the bead on the same surface. Figure 4 also shows the displacement on some selective nodes in terms of rotation. From this figure we can observe that the

nodes shows various displacement amount in each rotation and finally two nodes shows the zero value on the final or 7th rotation. And another node shows some displacement on the final or 7th rotation. This is because, on the final rotation those two beads were deleted from the rock surface. Thus they shows zero value on the final rotation. On the other hand, another node shows some displacement on the final rotation, because that node was attached on the rock body even on the final or 7th rotation.

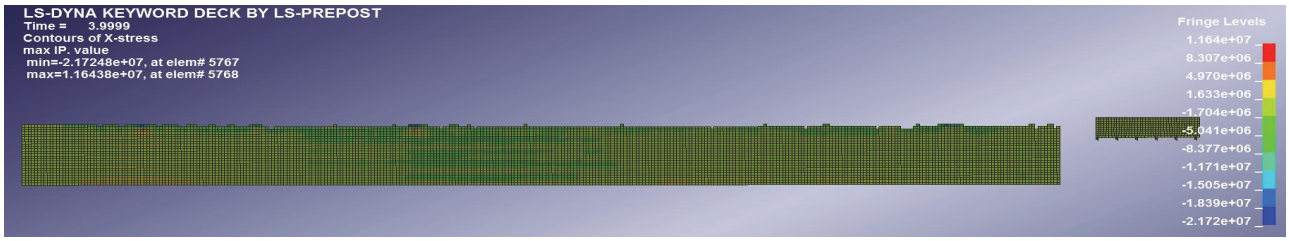

Fig. 2 After the First Rotation of the Bead

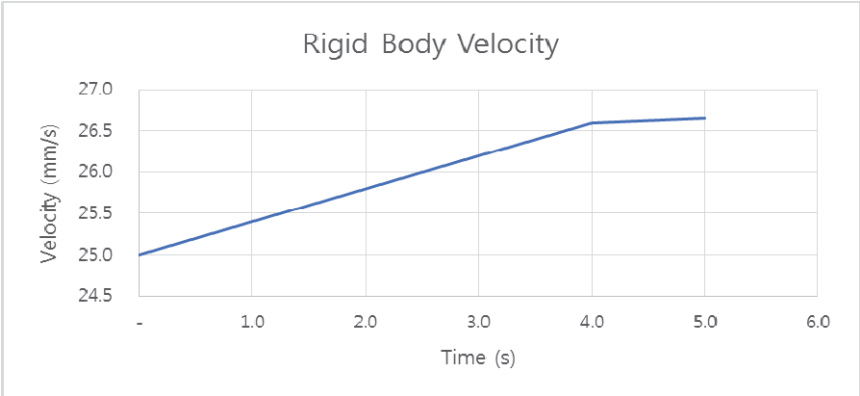

Fig. 3 Bead elocity

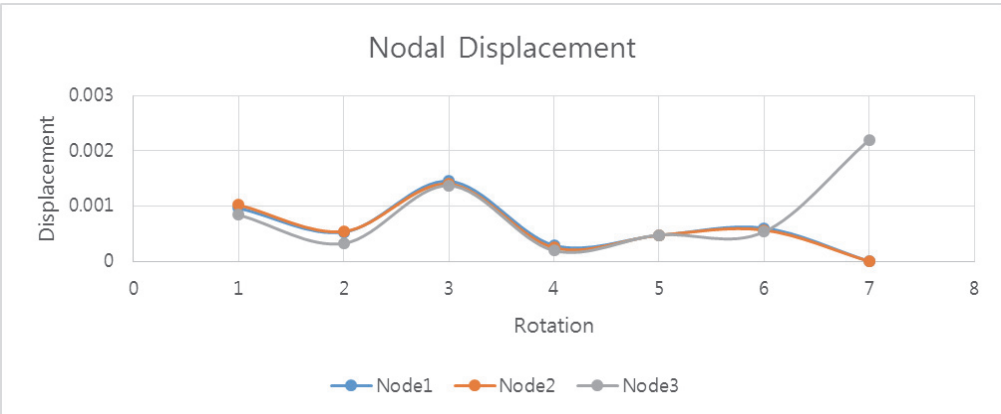

Fig. 4 Nodal Displacement on each Rotation

4. Conclusion

In this study the basic rock cutting process has been analyzed by an explicit FEM code, LS-DYNA. In this model two material has been assigned to each part, one is damaged material model for base rock and another is rigid body for cutter.

For the cutting process, a normal load has been applied to the cutter and a velocity has given to travel the whole rock surface. After some rotation or travel of the cutter, the cutting can be observed on the rock surface.

LS-DYNA could provide many various functions to study the cutting on different rock surface and conditions. By studying these material, cutting procedure could be improve.

Laboratory experiment will also be carry on in the field. The results from the field experiment could be compare with the simulation results. This could improve the each results and could help to reach a reference model regarding diamond wire cutting process.

6. References

1. Zhao min, Lang Xiying, Qi Fenglian and Lei Dongliang, Dynamic Analysis of the Diamond Saw Blade Cutting Granite based on LS-DYNA. School of Traffic and Mechanical Engineering, Shenyang Jianzhu University, Shenyang China.
2. A.Raczy, W.J.Altenhof and A. T. Alpas.8th International LS-DYNA Users Conference,Canada 2008, p.9-11
3. Pradeep L. Menezes, Michael R. Lovell, Ilya V. Avdeev, Jeen-Shang Lin, C. Fred Higgs III, Studies on the formation of discontinuous chips during rock cutting using an explicit finite element model. Int. J. Adv. Manuf Technol (2014) 70:635-648
4. Nils Gustafsson, Wire cutting as a complement to drill and blast in vibration sensitive environments. Chalmers University of Technology, Goteborg, Sweden.
5. LS-DYNA Theory Manual, Compiled By John O. Hallquist
6. “LS-DYNA 970 Keyword User’s Manual Volume I”, Livermore Software Technology Corporation, Livermore, CA (2003).
7. “LS-DYNA 970 Keyword User’s Manual Volume II”, Livermore Software Technology Corporation, Livermore, CA (2003)