







The same trend can be found for the energy release rate as shown in figure 6.

According to fracture mechanics, when the energy release rate reaches a critical value, the cracks will propagate. In figure 6, energy release rate achieves maximum when  $a_c/H$  equal to 0.4. It means that for fixed indentation peak load, the crack with the length ( $a_c/H \cong 0.4$ ) propagates most rapidly. So the relationship of between this crack length and indentation load can be taken as the scaling for indentation induced lateral cracking.

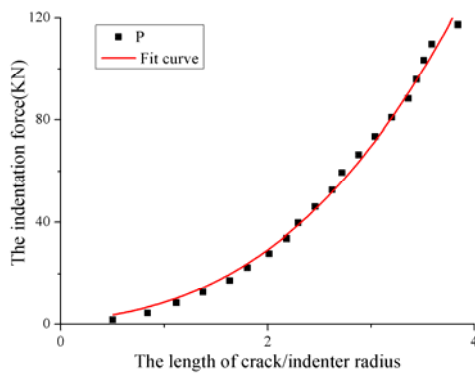


Figure 7. Relationship between the indentation force and that crack size

Accordingly, we numerically calculate the relationship between the critical length of crack and the indentation load, the result is plotted in figure 7. The indentation load is monotonically increase with the critical length that can be optimally fit as  $P = a(1 + a_c / R)^m$ ,  $a=1.04$ ,  $m=3$ .

#### IV. THE CONCLUSION

In this paper, we consider the lateral cracking under spherical indenter by penny shaped crack parallel to surface.

Effects of both inelastic deformation and unloading have been captured. The stress intensity of crack tip and the energy release rate are calculated numerically. The conclusion can be summarized as follows:

1) The dilatancy angle has a great influence on the stress intensity factor and the energy release rate. Consequently, it is appropriate to use Mohr-Coulomb criteria for description of the yield of rock materials. It implies that the dilatancy of rock has great impact on the fracture by indentation.

2) The different levels of unloading have a great influence on the stress intensity factor.

3) Relationship between the indentation force and that crack size has been obtained numerically.

#### REFERENCES

- [1] Lawn B. R., Swain M. V., Microfracture beneath point indentations in brittle solids, *J. Mater. Sci.*, 1975, 10, 113-122
- [2] Ostojic P., Mcpherson R., A review of indentation fracture theory: its development, principles and limitations, *Int. J. Fract.*, 1987, 33, 297-312
- [3] Lindqvist P. A., Stress fields and subsurface crack propagation of single and multiple rock indentation and disc Cutting, *Rock Mech. Rock Engng.*, 1984, 17, 97-112
- [4] Lawn B. R., Fuller E. R., Equilibrium penny-like cracks in indentation fracture, *J. Mater. Sci.*, 1975, 10, 2016-2024
- [5] Ahn Y., Lateral crack in abrasive wear of brittle materials, *JSME Int. J., Series A*, 2003, 46, 140-144
- [6] Chen X., Hutchinson J. W., The mechanics of indentation induced lateral cracking, *J. Am. Ceram. Soc.*, 2005, 88, 1233-1238
- [7] Mata, M., Casals O., Alcalá J., The plastic zone size in indentation experiments: the analogy with the expansion of a spherical cavity, *Int. J. Solids Struct.* 2006, 43, 5994-6013
- [8] Necati A., Stress intensity factors for a penny-shaped crack in a transversely isotropic layer bonded between two isotropic half spaces, *Z. Angew. Math. Mech.*, 2003 83, 409-418
- [9] Alehossein H., Detournay E., Huang H., An analytical model for the indentation of rocks by blunt tools, *Rock Mech. Rock Engng.*, 2000, 33, 267-284