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DETERMINING CRITICAL TIME OF ROCK DYNAMIC FRACTURE BY DYNAMIC MOIRE METHOD

YU YONG   ZHANG ZONGXIAN
College of Resource Engineering
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ABSTRACT An effective Dynamic Moire method was presented to determine the critical time of crack instable propagation in rock dynamic fracture. Two pieces of grating were installed near the notch of Short Rod specimen to form the Moire fringes, then the COD versus time could be monitored from the movement of the Moire fringes, and finally the critical time could be determined from the velocity of COD. This method was also compared with another one. It could be concluded that the critical time determined by Dynamic Moire method corresponds with that of the Transmitted Wave method at the loading rates from 10^3 to 10^4 MPa · $m^{1/2}$ · s^{-1}.

KEY WORDS rock, Moire method/dynamic fracture, critical time

IN the experiment of rock dynamic fracture, specimens were usually destroied in very short time as a result of impact loading. In dynamic fracture mechanics, critical time (also called critical point) is defined as the time point when crack reaches a critical length. Critical time for fracture is an important mechanic parameter related with the fracture characteristics of materials.

Generally, the mechanic characteristics of rock in fracturing are analysed with the load-time curve of specimen. Experiments for dynamic fracture are often carried out on Split Hopkinson Press Bar(SHPB), where a specimen is rapidly loaded by stress wave. From the load-time curve in rock dynamic fracture, we find that the load changes violently in a very short period, so a bit of measuring error could lead obvious divergence to correlative calculations.

But it is very difficult to determine the critical time. So far, there is no satisfied method in rock dynamic fracture to determine critical point, which blocks the development of experimental research in some way. To counter above situations, we adopted Dynamic Moire method and successfully solved this kind of problems.

1 EXPERIMENTAL PRINCIPLE AND METHOD

In our fracture experiment we recorded the COD (crack opening displacement)-time curve at first , and then we determined the critical time of rock fracture based on the COD

-time curve. The key problem of experiment was the testing of COD.

Grating was used to test displacement in our fracture experiment. Grating is a kind of optical component. With special technology, a group of equi- distance parallel lines are carved on glass and get a piece of grating. Overlapping two similar pieces of grating together and letting their grating lines cross at a very little angle, we can find the Moire fringes. The Moire fringes have two important characters. 1) The movement of Moire fringes is correspond with that of grating. Let d_a and d_f stand for the distances between two adjacent grating lines and between two adjacent fringes respectively, when a piece of grating moves a displacement d_a, the moire fringes will move a displacement d_f in the same time. As the moving direction of graitng changes, the Moire fringes wil also change their moving direction. 2) Moire fringes can magnify the displacement of grating. Usually, $d_f \gg d_a$. The less the angle of the crossing lines of two piece of grating, the bigger the magnifying power of Moire fringes. Making use of these characters, we were able to record the COD-time curve of Short Rod specimen during rock fracturing. The setup of experiment was shown in Fig. 1.

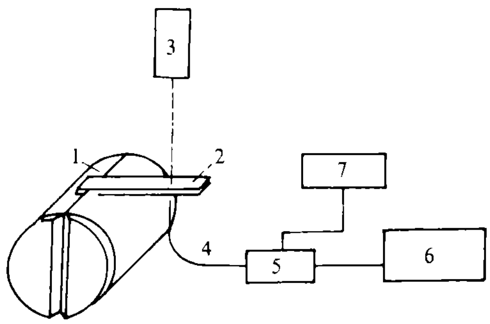

Fig. 1 COD Monitored by dynamic Moire Method

1 rock specimen; 2 grating ; 3 1 mW He-Ne laser ; 4 optical conductive fibre; 5 EMI 9804QB photomultiplier; 6 TCL 6-channel transient recorder; 7 high voltage power

The rock specimen was Short Rod(SR) fracture toughness specimen suggested by International Society of Rock Mechanics(ISRM)[1], the geometry and dimensions of SR specimen were illustrated in Fig. 2 and Table 1. Since an SR rock specimen is easy to prepare and it could evolve a crack automatically during fracturing, this kind of specimen was usually adopted as a rock fracture toughness specimen[2]. The tested rocks included gabbro and marble.

Before experiment, two pieces of similar gratings were sticked on the surface of SR specimen near the tip of crack. Adjusting the angle of the two pieces of grating, we could get proper Moire fringes. It was very essential to let the trend of Moire fringes perpendicular to the axle of the rock SR specimen, so that the movement of fringes was correspond with the COD of specimen. A laser beam shone vertically on the two pieces of overlapped grating, so the transmited optical signal was received by an optical conductive fibre and was delivered to a photomultiplier. The optical signal was changed into electric signal and was output to a channel of a transient recorder.

As to choosing grating, it was neccessary to pay attention to d_a. Since rock is a kind of brittle material, the COD of rock fracturing is very small, we should choose the grating whose d_a is small. In our experiment, two kinds of grating were used. Their d_a values were 1mm/200lines and 1mm/100lines.

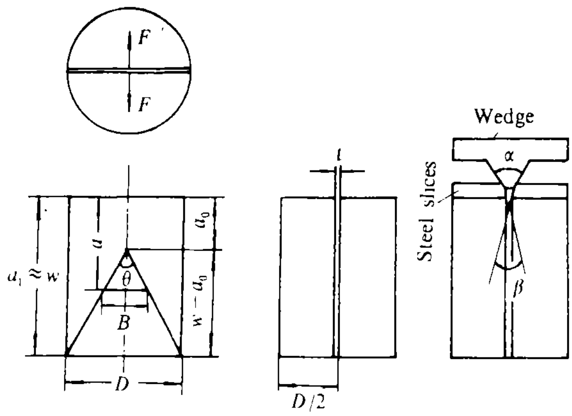

Fig. 2 The Short Rod specimen, wedge and steel slices

Table 1 The dimension of the Short Rod specimen [1]

Geometry parameter	Value	Tolerance
Specimen diameter	D	>10× grain size*
Specimen length, w	1.45D	±0.02D
Subtended chevron angle, θ	54.6°	±1.0°
Chevron V tip position, a_0	0.48D	±0.02D
Chevron length, $a_1 - a_0$	0.97D	±0.02D
Notch width, t	≤0.03D or 1 mm**	

* In this paper $D = 30$ mm ** Whichever is greater

2 EXPERIMENTAL RESULTS

Experiments were carried out on SHPB. A typical grating signal of displacement was shown in Fig. 3. It could be found that the signal changed periodially. Whenever the grating signal changed a period, the specimen' s crack occured a displacement of d_a. Correspondingly, the Moire fringes changed their brightness by the following patterns: bright-dark-bright or dark-bright-dark. When a moire fringe changed its brightness from the brightest to the darkest in a period, the value of grating signal changed from maximum to minimum as shown in Fig. 3 from T_1 to T_2. In the mean time there happened a displacement $1/2d_a$ to the specimen crack. Therefore, the more the signal periods, the larger the COD of SR specimen. The density of signals reflected the relative velocity of two pieces of grating. The bigger the density, the higher the velocity. Based on these principles, we could handle the experimental data with microcomputer, and could draw the COD−time curve and velocity-time curve of grating. They were both shown in Fig. 4.

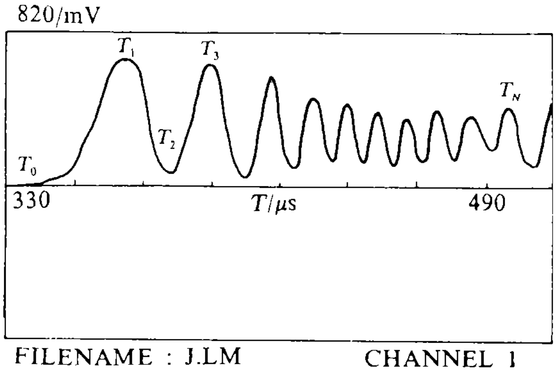

Fig. 3 The signal of grating displacement

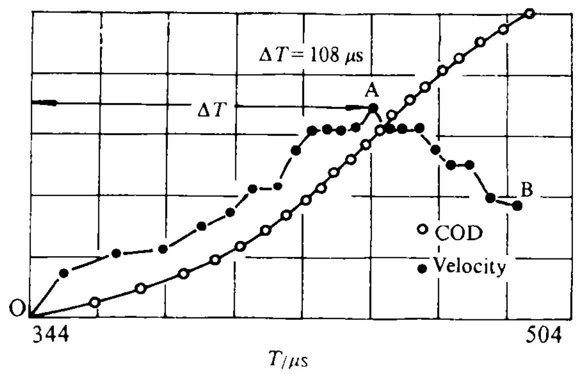

Fig. 4 The COD versus time and its velocity vs time

From Fig. 4, it could be found that the velocity of rock's COD increases gradually at the beginning point O, at that moment its acceleration is positive. When the velocity increases to a maximum(point A), the acceleration of COD is negative, seeing stage AB in Fig. 4. In stage OA, where the acceleration of COD is positive, cracks forms and spreads stably. As the stress wave of SHPB begin to load, a microcrack forms automatically at the tip of triangle area in SR specimen. With the loading going on, the crack expands gradually until it reaches a critical length. In that moment the specimen could not resist the increasing of load any longer, so the crack begins to spread instably and leads the specimen fracture. In the meantime, the velocity of crack spreading decreases due to unloading. From above analyses, we think that point A in Fig. 4 is the critical point for rock dynamic fracture.

In addition, in order to compare Dynamic Moire method with other ones, we also adopted another method: Transmitted Wave method. The method used transmitted wave signal of SHPB to determine critical time. The results of comparision are shown in Table 2. From Table 2 , we find that the results of Dynamic Moire method tallied with those of Transmitted Wave method. Therefore, as for rock dynamic fracture experiment at medum load rates, the maximum value-point of transimitted wave can be taken as fracture critical point, and the method can reduce the cost of experiment.

At last, the authors must point out that, the maximum-value point of transmitted wave may differ from critical point greatly at higher loading rates which $\dot{K} > 10^5$ MPa · $m^{1/2}$ · s^{-1} [2]. The authors will go on further research work about it.

Table 2 The comparision of the two methods to determine the critical time (μs)

Specimen code	Dynamic Moire Method	Transmitted Wave Method
02.LG	100	106
P.LM	101	100
S.LM	74	79.5
L.LM	106	92.5
J.LM	108	113

3 CONCLUSIONS

(1) The Dynamic Moire method introduced in this paper is reliable for determining rock fracturing critical point.

(2) The consistency of Transmitted Wave Method and Dynamic Moire Method shows that, at medium loading rates rock specimens are in the condition of quasi-static, inertia effect can be ignored. So, in SHPB dynamic experiment at loading rates from 10^3 to 10^4 MPa · $m^{1/2}$ · s^{-1}, the maximum value point of transmitted wave can be taken as the fracture critical point of rock specimen.

REFERENCES

1 ISRM. Int J Rock Mech Min Sci & Geomech Abstr, 1988, 25(2) : 71

2 Zhang Zongxian, Yu Yong, Zhao Qing. In : Rossmanith H P ed. Fracture and Damage of Concrete and Rock FDCR−2. E&FN SPON, 1993. 418

用动态云纹法测定岩石断裂失稳点

喻 勇　　张宗贤

北京科技大学资源工程学院，北京 100083

摘要 介绍了一种用于测定岩石断裂失稳点的先进方法－动态云纹法. 在岩石断裂韧度试件的表面裂缝处粘贴两片透明光栅,使之形成莫尔条纹. 通过光电装置记录下断裂过程中裂缝开口位移随时间的变化情况,进而根据位移速度的快慢变化来确定岩石试件的断裂失稳点.实验中还将动态云纹法的实验结果同其他方法作了比较,结果表明,在加载率 10^3～ 10^4MPa · $m^{1/2}$ · s^{-1} 范围内，岩石试件的最大载荷点即为断裂失稳点.

关键词 云纹法/动态断裂，失稳点