Study on Shock Response of Multi Particle Coal and Gangue Impacting Metal Plate

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Abstract

In order to study the shock response of a large number of coal and gangue mixture to impact tail beam during coal caving process, obtain different vibration signals of coal and gangue to realizing intelligent recognition of coal and gangue. Taking two elastic balls impact rigid plate model as an example, using the impact function to establish a theoretical model and using Adams for simulation. The effects of velocity, material properties and energy loss on impact results are obtained. The research results provide a reference for vibration recognition technology of coal and gangue, and promote the realization of intelligent coal caving in coal mining face.

Keywords

Impact response; Adams; Coal and gangue identification.

1. Introduction

The key problem to advance the automatic process of coal mining face is realizing the automatic recognition of coal and gangue and intelligent control of coal caving time. At present, the control methods of coal caving time are mainly manual observation and program control of electro-hydraulic valve. These two methods have strict requirements on the mining environment and can't achieve feedback control according to coal seam reserves. When the coal reserves are changed, if the coal caving time can't be adjusted according to the degree of coal-drop in time, it is easy to see the waste of resources and the decline of coal quality. To accurately grasp the coal caving time and realize high efficiency and high production of coal, the automatic recognition technology of coal and gangue must be vigorously developed. In the current coal and gangue identification methods, the vibration recognition method has high safety and low use cost, and can adapt to complex mining environment, and it is an important means to realize the intelligent separation of coal and gangue.

2. Collision contact model of Adams

Collision is a complex transient dynamic problem, the collision system produces a great deal of energy change in a very short time, the motion state of the colliding body changes abruptly, and there will be great instantaneous contact force on the contact surface at the same time. The theoretical studies at the present stage have pointed out that when two objects collide at a certain initial speed, there will be some contact deformation of two objects in the contact area due to inertia. Until the relative velocity of two contact objects is zero, the deformation reaches the maximum. This process is called the compression process. When the compression process is over, the extrusion deformation produced by impact contact will gradually recover. And until the two object no longer contacts, the extrusion deformation completely disappears. This process is called the recovery process of the collision. Adams establishes the system dynamics equation by using the Lagrange equation method in the theory of multi-body system dynamics. The impact function method in Adams is used to calculate the impact contact problem, and it is equivalent to the nonlinear spring-damping model. The impact force defined by the impact function consists of the elastic force generated by the mutual extrusion and the damping force generated by the relative velocity, which can be expressed as follows

$$F_n=\begin{cases} 0 & q>q_0 \\ k(q_0\text{-}q)^e\text{-}c(dq/dt)\text{step}(q,q_0\text{-}d,1,q_0,0) & q\le q_0 \end{cases} \tag{1}$$

Where q_0 , q are the initial relative distance and the actual relative distance of two objects, respectively; dq/dt is the actual relative velocity of two objects; k is the stiffness coefficient; e is the nonlinear exponent; c is the maximum damping coefficient and d is the maximum penetration depth

The stiffness coefficient k is closely related to the material properties and external shape of the colliding object, and is an important parameter. It can be determined by the Hertz impact theory, which is given by

$$k=\frac{4}{3}ER^{1/2} \tag{4}$$

$$R=\frac{R_1R_2}{R_1+R_2} \tag{5}$$

$$\frac{1}{E}=\frac{1\text{-}v_1^2}{E_1}+\frac{1\text{-}v_2^2}{E_2} \tag{6}$$

Where R_1 and R_2 are the radius of curvature of two contact objects, E_1 and E_2 are the modulus of elasticity of two collision objects, v_1 and v_2 are the Poisson's ratio of two collision objects.

3. Three-dimensional model of multi particle coal gangue impacting rigid plate

In the process of fully mechanized caving mining, the working condition of coal mining face is complex. With the development of coal mining, the reserves of top coal gradually decreases, and a large number of coal and gangue mixture will fall on the tail beam of the hydraulic support. In order to study the impact response on the tail beam in this process, simplifying the coal or gangue into elastic spheres, simplifying the tail beam into a rigid plate fixed on the ground. Ignoring air resistance and material surface friction and establishing the model as shown in Fig. 1. The model material required for the simulation is shown in Table 1. Under different working conditions, studying the dynamic response of two elastic balls impacting rigid plates .

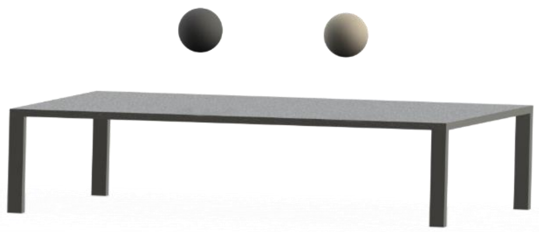

Fig. 1 Collision model of multi-particle coal and gangue

Table1 The material properties of model

Model	Material	Density/kg · m^{-3}	Modulus of elasticity/Pa	Poisson's ratio	Size/m
Elastic ball	Coal	1380	5.3×10^9	0.32	R=0.03
Elastic ball	Sandstone	2487	1.35×10^{10}	0.123	R=0.03
Rigid plate	Carbon steel	7850	2.06×10^{11}	0.28	$0.6\times0.6\times0.01$

4. Dynamic simulation and analysis

4.1 The effect of velocity on the impact results

The materials of the two balls are all coal, in order to distinguish them, two elastic balls are respectively recorded as A and B. The initial speed of A is 1m/s, and the initial speed of B is 2m/s (downward). The simulation results are shown in Fig. 2 to Fig. 4.

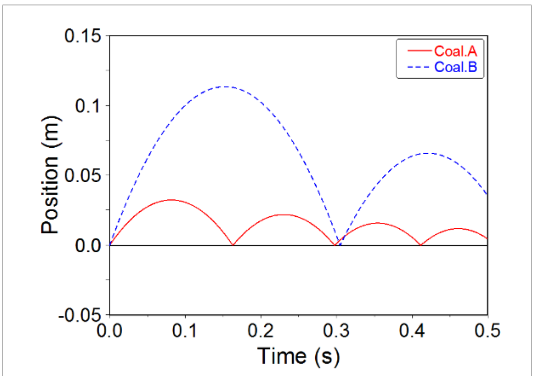

Fig. 2 Position

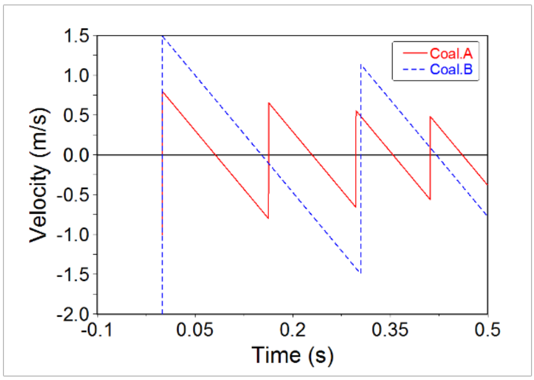

Fig. 3 Velocity

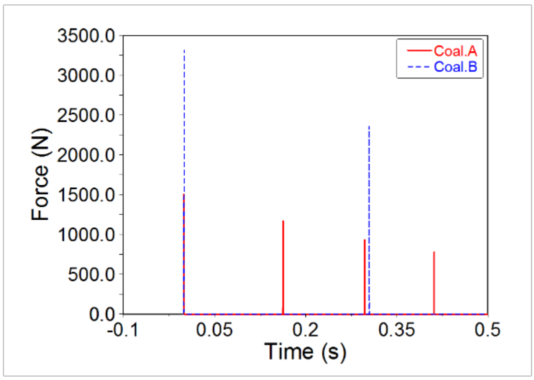

Fig. 4 Collision force

It can be seen from Fig. 2 that the rebound distance decreases with the increase of collision times, and after the first collision, the rebound distance of the rock ball will reach the maximum value in the whole collision process. Due to the existence of damping in the system, each collision will consume part of the energy, resulting in a gradual reduction in the rebound distance. The peak value of rebound distance of B is larger than that of A, and the time to reach the peak value is larger than that of A. But in the simulation time, the collision frequency of A is faster. In Fig. 3, when the collision occurs, the velocity mutates in a very short time. The value of the velocity becomes smaller and the direction of it becomes reverse. And the velocity of the rock ball with lower initial velocity varies faster. Considering the respective recovery coefficients of the two rock balls after the first collision, it can be seen that the impact recovery coefficients of the two balls are basically the same. This shows that the impact recovery coefficient of materials is basically unchanged under the condition of little difference in velocity. The collision force shown in Fig. 4 is pulse force, which occurs only when a collision occurs. The collision force reaches the maximum value in the first collision and then decreases in turn. Through the above three diagrams, it can be found that the velocity has an influence on the impact result. After the same number of collisions, the rebound distance of the rock ball with higher initial velocity is higher and the rebound velocity is greater. And the greater the initial velocity of the rock ball, the greater the instantaneous collision force produced during each collision.

4.2 The Effect of material properties on impact results

The materials of the two elastic balls are coal and sandstone, respectively. Causing them collide with the rigid plate at the initial speed of 1m/s. The simulation results are shown in Fig. 5 to Fig. 7.

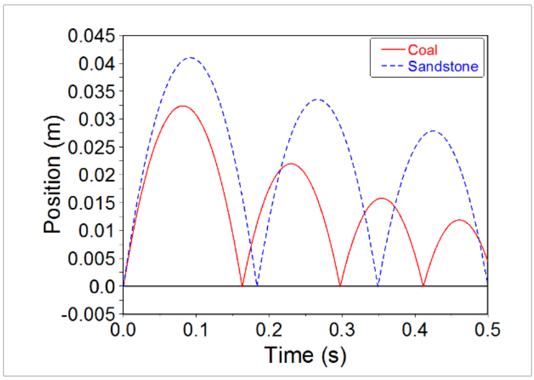

Fig. 5 Position

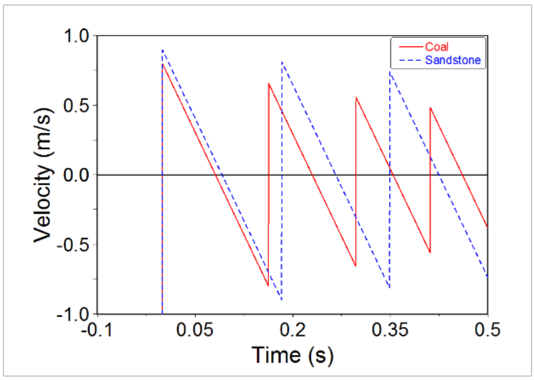

Fig. 6 Velocity

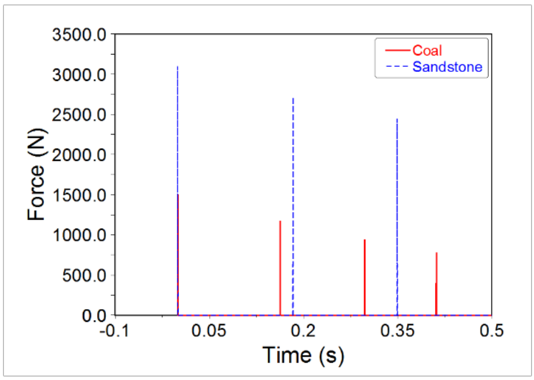

Fig. 7 Collision force

It can be seen from Fig. 5 that the rebound distance of coal is less than that of sandstone after the same collision. However, when the two rock balls collide with the rigid plate at the same time, the coal ball reaches the peak of rebound height in a shorter time. And within a certain period of time, the number of collisions between the coal ball and the rigid plate is more, and the collision frequency is higher. It can be seen from Fig. 6 that when the initial velocity is the same, the rebound speed of the sandstone is larger than that of the coal. This indicates that the impact recovery coefficient of sandstone is greater than that of coal under the same conditions（the same radius and initial velocity）. During the collision process, the velocity of sandstone decreases more slowly. This is because the properties of materials are different and their mechanical properties are different. The mechanical properties of sandstone are stronger than that of coal, so the velocity of sandstone is more difficult to change. As shown in Fig. 7, the collision force of sandstone is much larger than that of coal when each collision occurs. According to Eq. (1), the stiffness coefficient *k* is the main factor determining the magnitude of collision force. The stiffness coefficient of sandstone is much larger than that of coal, so the impact force of sandstone is greater.

4.3 The Effect of energy loss on impact results

The energy loss caused by collisions between rock ball and rigid plates of different materials is different. In order to investigate the influence of energy loss of different materials on the impact response, causing the two rock balls have the same initial kinetic energy. Based on the kinetic energy of sandstone, the initial velocity of sandstone is set to 1m/s, and the initial velocity of coal is set to 1.3425m/s. The simulation results are shown in Fig. 8 to Fig. 10.

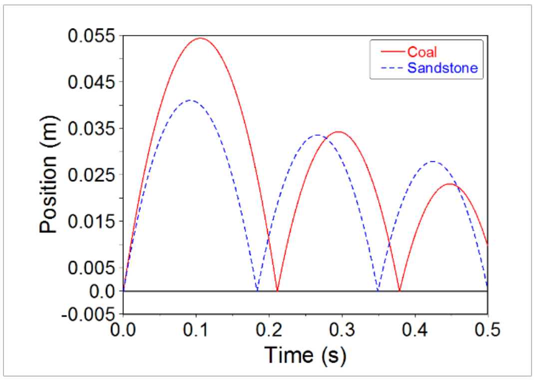

Fig. 8 Position

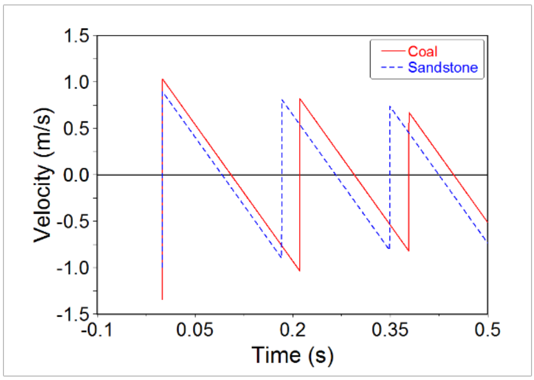

Fig. 9 Velocity

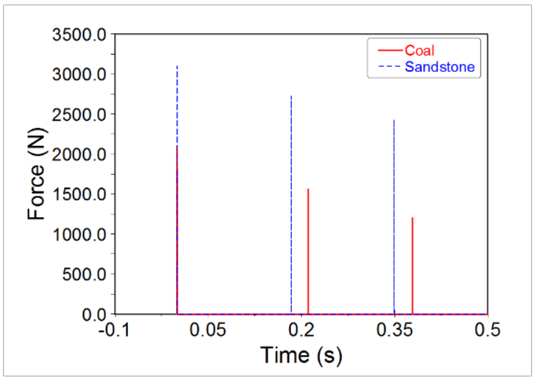

Fig. 10 Collision force

It can be seen from Fig. 8 that under the same initial kinetic energy, after the first two collisions, the rebound distance of the coal is larger than that of the sandstone, but after the third collision, the rebound distance of the coal is smaller than that of the sandstone. The velocity shown in Fig. 9 is also the case. The rebound velocity of coal is larger than that of sandstone after the first two collisions, but the rebound velocity of coal after the third collision is smaller than that of sandstone. And the variation range of rebound distance and rebound velocity of coal is larger than that of sandstone after each collision. This is due to the poor mechanical properties of coal, which consumes more energy each time it collides. The total energy of coal will be depleted faster than that of sandstone, and the result is that the rebound velocity and rebound distance of coal varies greatly. After repeated collisions, the coal will first achieve static equilibrium. In Fig. 10, although the rebound distance and rebound velocity of coal after the first two collisions are larger than those of sandstone, due to the poor mechanical properties of coal, the stiffness coefficient is relatively small, and the impact contact force produced by each collision is small.

5. Conclusion

Through the simulation and analysis of two rock balls impact the same rigid plate under different working conditions, the following conclusions can be drawn:

(1) Velocity has greater influence on rebound distance and impact force of rock balls. The maximum rebound distance and maximum collision force of rock balls will increase with the initial velocity. After the same number of collisions between the rock ball and rigid plate, the rebound distance and rebound velocity of the larger initial rock balls are larger. After the same number of collisions, the rebound distance and rebound velocity of the rock ball with larger initial velocity are larger.

(2) Material properties are the important factors that affect the result of collision. The difference of material properties will lead to differences in mechanical properties of materials. Under the same conditions, the material with strong mechanical properties has greater collision force when colliding. The rebound distance and rebound velocity are larger after collision, and the change trend of rebound

velocity is relatively gentle. In a certain time, the collision frequency of materials with poor mechanical properties is higher and the collision time interval is smaller.

(3) The energy loss caused by collision has an important influence on the impact response, and different energy losses will make significant difference in the collision results， and the difference in energy loss will result in significant differences in collision results. In cases where the velocity is not much different, materials with poor mechanical properties consume more energy during collisions. As a result, the collision force produced by collision is small, and the rebound distance and rebound velocity vary greatly.

(4) The difference in impact response of coal and gangue is the basis for realizing vibration identification of coal and gangue. The vibration recognition method realizes the automatic identification of coal or gangue by distinguishing the different impact responses of them under the same working conditions. The study of shock response will provide references for vibration separation of coal and gangue mixture underground. And it is of great significance for realizing intelligent coal mining and unmanned coal mining face.

Acknowledgements

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