Study on the Response Characteristics of Coal or Gangue Impact Metal Plates Based on Ls-dyna

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Abstract

Coal or gangue as different material properties of rock impact hydraulic supports will produce different vibration response when comprehensive mechanized top coal caving mining. In order to study the response mechanism and the difference of vibration signal during the collision between coal, gangue and the upper metal plate of the tail beam, the dynamic simulation model of rock (including coal and gangue) impacting metal plate was established by using Ls-dyna, and the impact response of the system under different working conditions was obtained. Based on this, the vibration mechanism of single particle rock impinging metal plates at different impact velocities was studied. Through the comparison and analysis, the vibration response of coal and gangue in the contact process was quite different, the results can provide reference for the identification of coal gangue through vibration.

Keywords

Coal gangue recognition;,Ls-dyna, Impact behaviour, Vibration.

1. Introduction

In the field of coal mining, comprehensive mechanized caving mining is a method for mining thick coal seams or extra-thick coal seams, the automatic identification technology of coal gangue in coal caving process is the key to realize its automatic mining. If the top coal less put, it will reduce the utilization of coal, if the top coal over put, it will reduce the quality of coal mining. At present, most of the common coal gangue identification technology is image recognition or ray recognition, the procedure is cumbersome and the recognition rate is low. In the process of coal falling, coal and gangue as rock with different material properties will produce different vibration signals when impacting the hydraulic support, which can provide a new way to study coal gangue identification.

As a nonlinear explicit dynamic analysis program, Ls-dyna is widely used in impact dynamics analysis because of its rich material Model library and practical automatic contact analysis function. This paper applies it to the study of the foundation of the rock impact metal plate, simulates the vibrating condition of the single rock impacting metal plates under different impact velocities, and studies the vibration characteristics of the rock and the metal plate in the collision process, which provides a reference for the coal gangue identification research based on the falling coal impact vibration signal.

2. Collision contact theory

The Herz contact theory is generally used in the study of the collision problems such as simple shape, small deformation and no friction loss. When two objects collide, the normal contact Force *Tn* and the deformation displacement *y* are produced on the contact surface, The relationship between the two is as follows:

$$y=\left(\frac{9T_n^2}{16ER^2}\right) \tag{1}$$

$$R=\frac{R_1R_2}{R_1+R_2} \tag{2}$$

$$E = \frac{E_1 E_1}{E_2(1-\mu_1^2)+E_1(1-\mu_2^2)} \quad (3)$$

Where R_i is the contact curvature radius of rock and metal plate at collision point, When *i*=1, it means rock, *i* =2,it means metal plate. *Ei* is young's modulus, μ_i is Poisson's ratio.

The normal contact force on the contact surface is

$$T_n=\frac{4}{3}ER_1^{\frac{1}{2}}y^{\frac{3}{2}} \quad (4)$$

In a system in which a single particle sphere impacting a flat plate, the moment of impacting between the rock and the metal plate will produce a huge energy change, and according to the principle of conservation of energy, energy neither produces nor disappears, it transforms from one form to another.

The initial kinetic energy *G* of the rock is

$$G=\frac{1}{2}mv^2 \quad (5)$$

Where *m* is the mass of rock, *v* is the impact velocity. In the process of collision contact, if only elastic deformation is considered, the system satisfies the law of conservation of energy, namely

$$\frac{1}{2}mv^2=\int\frac{4}{3}ER_I^{\frac{1}{2}}y^{\frac{3}{2}} \quad (6)$$

Can be drawn:

$$y=\left(\frac{15mv^2}{16ER_1^{\frac{1}{2}}}\right)^{\frac{2}{5}} \quad (7)$$

$$T_n=\frac{4}{3}ER_1^{\frac{1}{2}}\left(\frac{15mv^2}{16ER_1^{\frac{1}{2}}}\right)^{\frac{3}{5}} \quad (8)$$

On this basis, the recovery coefficient n is introduced, and the loss of the kinetic energy of the ball ΔG is

$$\Delta G=\frac{1}{2}m\Delta v^2(1-n^2) \quad (9)$$

Where Δv is the velocity difference before two objects collide.

Accordingly, According to this, the expression regarding the impact velocity *v* of the contact force T_n and the displacement y of collision contact point at the time of collision can be determined.

The expression of the contact Force T_n and the impact velocity *v* of the collision contact point Displacement y can be determined. The energy of rock loss in collision is related to the coefficient of collision recovery and impact velocity.

3. Dynamic simulation

Through the Ls-dyna software, the dynamic modeling and simulation of single rock impact metal plate under different impact velocities were carried out. In this study, the plate was a thin metal plate and uniform continuous medium, rock includes two types of coal and gangue. The rock impacted metal plates at speeds of 5m/s, 10m/s, and 15m/s, respectively. Coal and gangue were of the same size and have different properties.

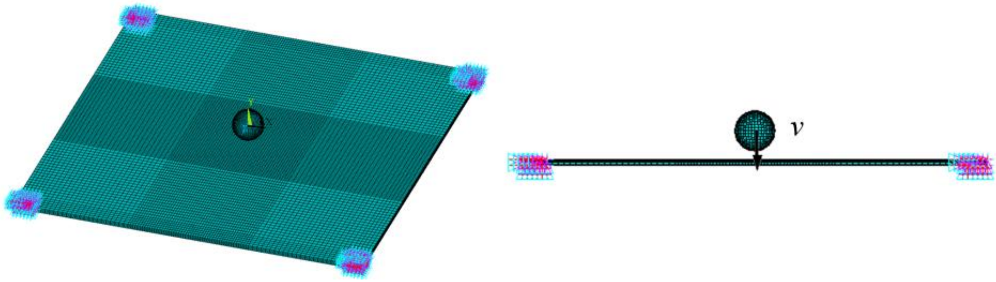


Fig.1 Finite Element Modeling

To better simulate the impact of collisions, the contact area between the metal plate and the rock was mesh-encrypted, and the boundary constraint were applied to the front and back surfaces of the four corners of the metal plate, as shown in Figure 1. Because the contact behavior was complex non-linear contact, the contact type was set to face-surface automatic contact, and the rock was the contact surface, and the metal plate was the target surface.

In this study, the crushing of coal ramming impact was not considered, so the elasto-plastic model was used. The material model parameters of coal, gangue and metal plate are shown in Table 1.

Table.1 Material Model Parameters of coal, gangue metal plate

Material model	Density /kg.m^{-3}	Young's Modulus/Pa	Poisson's ratio
Coal	1380	2.26x109	0.28
Gangue	2400	3.906 x109	0.29
Metal plate	7850	2.1x1011	0.3

4. Results analysis

Through the ls-prepost post-processing program to get the impact response of the system collision. The energy-time history, displacement, velocity, acceleration and contact force of rock were obtained.

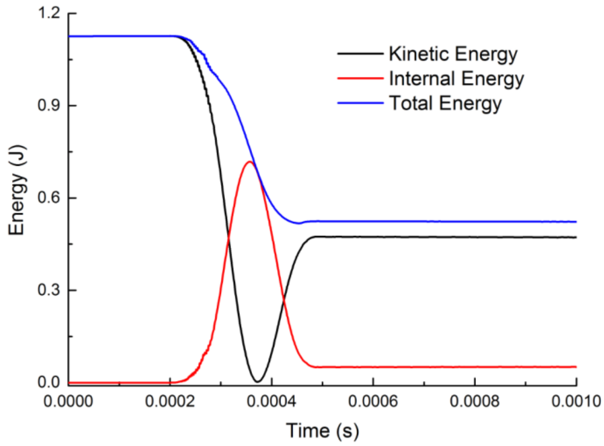
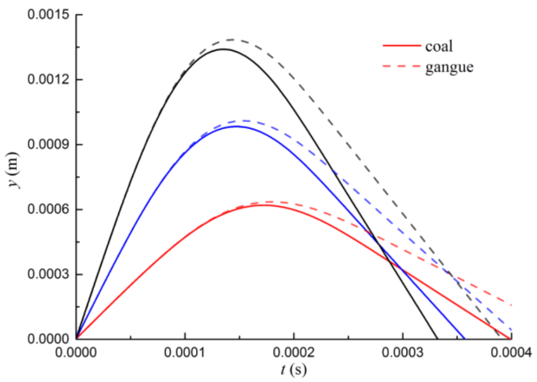


Fig.2 Energy-time history of coal at impact velocity 5m/s

In the study of energy conversion, the rock takes coal as an example, in Fig. 2, the energy history of coal at an impact velocity of 5m/s, Before the two bodies come into contact, the energy of the rocks comes from kinetic energy. In the process of collision contact, Kinetic energy was converted into internal energy, the kinetic energies were reduced, the internal energy was increased, the kinetic energy was 0 when the contact point displacement was maximum. Then the rock began to rebound, the internal energy gradually decreased and the kinetic gradually energy increased. At the end of the contact, kinetic energy and internal energy remained steady. In the simulation, there was damping consumption in the contact process, and the rock transmitted some energy to the metal plate, so the total energy of the rock decreased gradually during the collision contact.



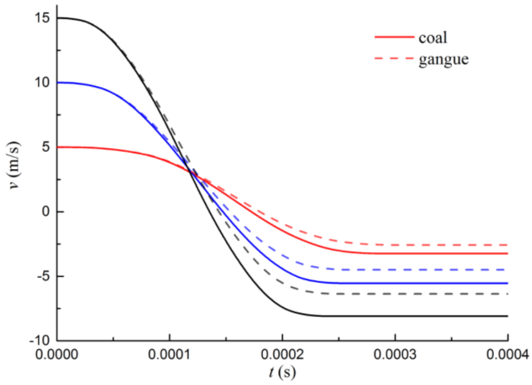
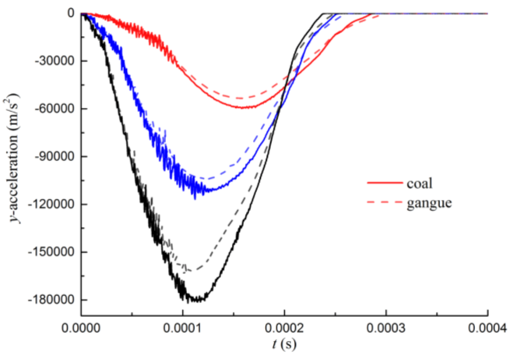


Fig.3 Normal displacement - time history of rock Fig.4 Normal velocity - time history rock

Fig. 3 is that the normal displacement of rock varies with time. The larger the energy of the rock when it impacts, the greater the displacement. The greater the impact velocity, the faster the displacement changes and the smaller the collision contact time. When coal or gangue of the same size impact the metal plate at the same speed, the displacement of the gangue contact point is larger than that of coal and the contact time is slightly longer than coal.

Fig. 4 is that the normal velocity-time curve of coal, the higher the impact velocity, the greater the impact energy of rock, the greater the residual velocity at the end of the collision, the faster the rate of kinetic energy change. And the same impact speed of coal and gangue, coal kinetic energy change faster than coal, coal collision residual speed is greater than gangue.



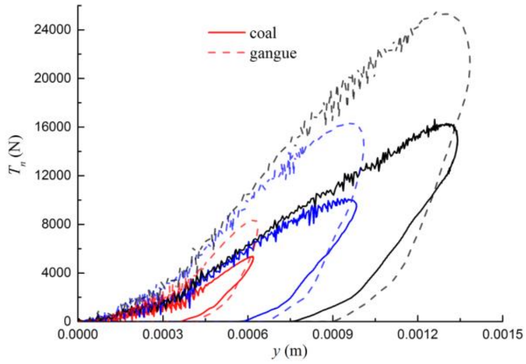


Fig.5 Normal acceleration-time history of rock Fig.6 Contact force-displacement curve of rock

Fig.5 shows the normal acceleration-time curve of the rock. The greater the impact velocity, the greater the acceleration during the contact. When the same size of coal and gangue impact metal plate, the acceleration of coal is greater than the gangue.

Fig.6 shows the contact force-displacement curve of rock. It can be concluded that the greater the impact velocity of the rock, the greater the maximum displacement of the contact point, and the displacement of contact point increases first and then decreases. Before reaching the maximum displacement, In the same deformation, the greater the impact speed, the greater the contact load, and the contact load of gangue is larger than coal. But after the rock reaches the maximum displacement, the rate of the displacement rebound of the rock with the same attribute is basically the same.

Fig.7 and Fig.8 show the simulation and theoretical comparison of contact point displacement and contact force at different impact velocities. The maximum contact point displacement of simulation is slightly lager than the theory, but two trends are basically the same. Because in the simulation, there is deflection deformation of the metal plate, and in the theory, only the elastic deformation of the metal plate surface is considered. The contact force in the simulation results is slightly less than the theory, because the deformation of the plate in the simulation reduces the contact stiffness of the system, resulting in a smaller contact force of the system. As the impact speed increases, the difference between the simulation and theoretical results is greater, but the growth trend is roughly the same.

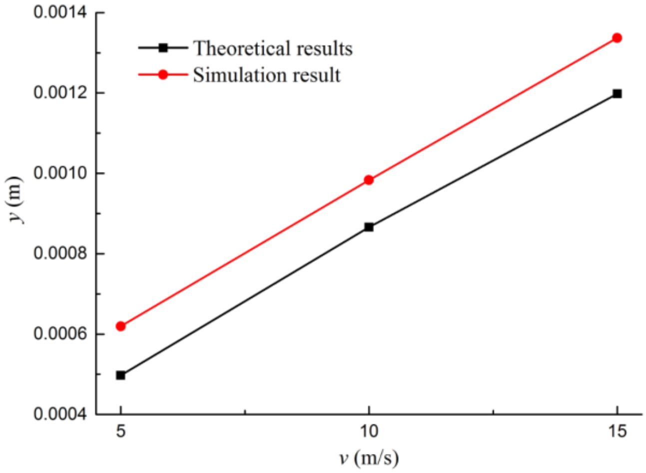


Fig.7 Displacement of contact point under different impact velocities

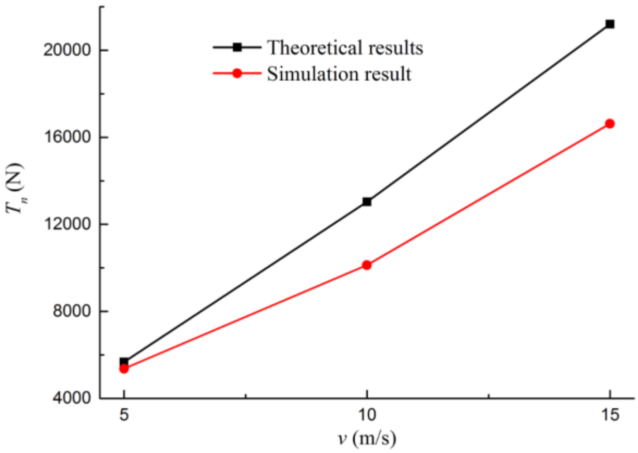


Fig.8 contact force under different impact velocities

5. Conclusion

In the course of collision, the impact response of rock is related to impact velocity, rock radius and material properties. Through the study of impact response characteristics, during the collision, the kinetic energy of the rock is mainly converted into the internal energy of the rock and transferred to the metal plate. The larger the impact speed of rock, the greater the impact energy, the greater the displacement of the contact point, the shorter the contact time, the greater the collision residual velocity and the contact force. For the same size of coal and gangue, the impact residual velocity and acceleration of coal are larger than that of gangue, and the displacement of contact point, contact time and contact force are smaller than the gangue.

The maximum displacement of the contact point obtained by the simulation is slightly lager than the theory, because there is a deflection of the metal plate in the simulation, which reduces the contact stiffness of the system and reduces the contact force.

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