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Design and Application of High Energy Collision Flexible Buffer

Yu Guang-bin[1*], Guan Yan-qi[1], Yang Xiao-hui[2] and Bu Jing-yuan[1]

[1]School of Mechanical and Power Engineering, Harbin University of Science and Technology, Harbin, Heilongjiang 150080, China
[2]China Coal Research Institute, Beijing 100013; China
[*]593542635@qq.com

Abstract

Introduces a suitable for steep inclined shaft sports car flexible buffer design method, given the high energy collisions flexible buffer mathematical model and simulation test is conducted, designed a high energy collision flexible buffer, to solve the problem of conventional buffer buffer distance is too long, the vehicle off road and so on, through the friction between the wire rope and the buffer to absorb the energy of the sports car, and realize the effective interception of the vehicle, ensure that the vehicle has a short distance to stop the car, and ensure the safe and reliable operation of the anti-car system. To ensure the safety of coal mine rail transport is of great significance.

Keywords*: Mine; Inclined car; Collision flexible*

1. Introduction

Mine transportation safety accident is second only to the second disaster of roof accidents and inclined well sports car is the most serious accident in the transportation safety. According to incomplete statistics, in 2011, the national coal mine transportation accident casualties accounted for 20% of the accident of coal production is the total number of casualties, and inclined well sports car accounted for 15% of the traffic accidents, so pay attention to the inclined well catcher work for the coal mine production safety is very important. Sports car door device is with the car arrester and Scotch bar and together referred to as the "slope of a three block" in a form of protection is installed in mine oblique lane, at the wellhead block car column of a protective device [1-3].

The buffer is a device that is installed in the absorption of the sports car in the inclined tunnel, at present, the domestic and international buffers are mainly divided into two categories, one is installed on the track and the other is installed on the vehicle. Install the in orbit energy absorbing device is divided into three types: friction energy absorption device, Lang and energy absorber, Zelda energy absorber; installation on the vehicle energy absorption device mainly has two types: brake force steeplechase and change the energy absorber, the brake force does not change steeplechase energy absorber. Although structure of different types of buffer in a certain extent plays a uncontrolled release energy of the car, but due to the length of the roadway inclined, number of cars and other factors impact on, resulting in buffer distance is too long, the vehicle off phenomenon. A new generation of the buffer adopts the high energy of flexible collision technology, better combines the characteristics of buffer distance and buffering capacity, the barrier of wire rope card on the rope groove of the buffer, using an adjusting bolt will be pressed by the steel wire rope, energy by the friction force between the steel wire and buffer to absorb the coupe, by adjusting the tightening bolt tightening degree to different resistance values to better cushioning effect.

[*] Corresponding Author

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2. High Energy Collision Model

2.1. A Simplified Model of the Relationship in the Process of Front Crash Acceleration Car in Time

In the car frontal collision, in the collision occurred in a short time, the mine car will produce a large acceleration, direction is opposite to the direction of the acceleration and the moving car; in this at the same time, coal tub due to the existence of inertial force, the corresponding produced an acceleration, is same with the direction of movement of the car. Indicates this, below the figure of acceleration values are positive, namely the acceleration size.

Tramcar in collision, collision energy absorption rely mainly on to installation in inclined roadway in the buffer. The buffer adopts the high-energy flexible collision technology, better combined with the characteristics of the buffer distance and buffering capacity, the barrier of wire rope card on the rope groove of the buffer, using an adjusting bolt will be pressed by the steel wire rope, energy by the friction force between the steel wire and buffer to absorb the coupe, by adjusting the tightening bolt tightening degree to different resistance values, to better cushioning effect [4-6].

(1)The acceleration of the body in the process of collision is divided into two main stages: in the initial stage of the collision, the body acceleration has a large peak, followed by the body and energy absorbing parts of the deformation, which is in a relatively stable stage.

(2)The peak acceleration is usually 2~4 times higher than that of the stationary phase.

Below we according to this phenomenon, simplified model of car acceleration in a collision - time relationship.

In theory we can analyze, due to the collision is car braking energy absorbed by kinetic energy, so:

$$\int R(t)\Delta s dt = \frac{1}{2}m\left(v^2_{mo} - v_0{}^2\right) \tag{1}$$

Where *s* is the braking distance of tramcar collision process; *m* is the vehicle total mass under full load condition; *R(t)* is the car collision process by the resistance; v_{mo},v_0 is the end of the car speed and initial velocity.

At the same time, the car produced in the collision acceleration:

$$A(t) = \frac{R(t)}{m} \tag{2}$$

Here a and R are according to the collision happened time and constantly changing. Because the car collision time is very short (about 0.1 s), so in the establishment of simplified model can be simplified as follows：

1. In the collision process, car by force of laneway is replaced by the average force, the force constant size, change with time change.

2. The acceleration of tramcar collision can be represented by the average acceleration.

At the end of the known speed tramcar collision is 0, then (1) can be the following approximate transformation:

$$\int R(t)\Delta s dt = \frac{1}{2}m\left(v^2_{mo} - v_0{}^2\right)$$

$$ma \cdot s = \frac{1}{2}mv_0^2$$

$$a = \frac{v_0^2}{2s} \tag{3}$$

Because in the process of tramcar collision, the constant acceleration, the speed change a certain amount, so the collision duration time t can be expressed as:

$$T = \frac{v_0}{a} \tag{4}$$

By the known data, the brake initial time skip the maximum rate of decline:
$v_0 = 25.6 m/s$
Buffer distance of braking process:

$$S = \frac{v_0}{2j} \tag{5}$$

Where S is the buffer distance of braking process; j is the artificially set braking deceleration.

2.2. The Car in the Collision Process, the Simplified Model of the High Flexible Buffer, Stress Analysis and Design

Model and hypothesis in the car collision, car contained ore and car acceleration values are the same (acceleration), it will car contained ore and mine is simplified as a whole car model, established in the car collision simplified model and stress analysis.

For the car, we performed along the dip direction of drift and vertical in the tunnel carries on the stress analysis and calculation. According to the model above, we will mine by stress concentration in a simplified, and follows the force calculation [7].

A simplified model of car collision analysis and stress diagram as follows Figure 1:

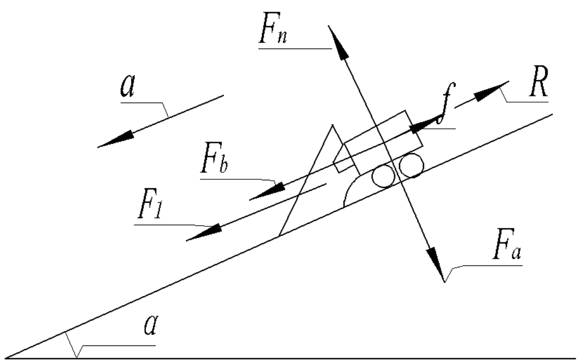


Figure 1. A Simplified Model of Tramcar and Barrier Collision at

The significance of the relevant symbols in Figure 1 is as follows:

Where a is the tramcar collision acceleration; F_a,F_b is the tramcar component of gravity; R is the brake resistance barrier.F_1 is the barrier by tramcar pressure; F_n is the support force of the tramcar on the inclined roadway; α is the inclined angle; f is the friction between the tramcar and the inclined roadway.

$$F_a \cos\alpha + F_1 \sin\alpha = mg \tag{6}$$

$$f + R = G\sin\alpha \tag{7}$$

$$f = uF_n \tag{8}$$

$$F_n = mg\cos\alpha \tag{9}$$

2.3. Analysis on the Stress Analysis of Partially Simplified Model of Buffer

(1)Hypothesis:

1. in the event of a collision, the buffer strength is large enough, in the process of collision does not occur deformation, can be seen as a rigid body.
2. buffer is not affected by other side force.
3. buffer parts are simplified to focus on one point.

Based on the above assumptions, the establishment of the following 2:

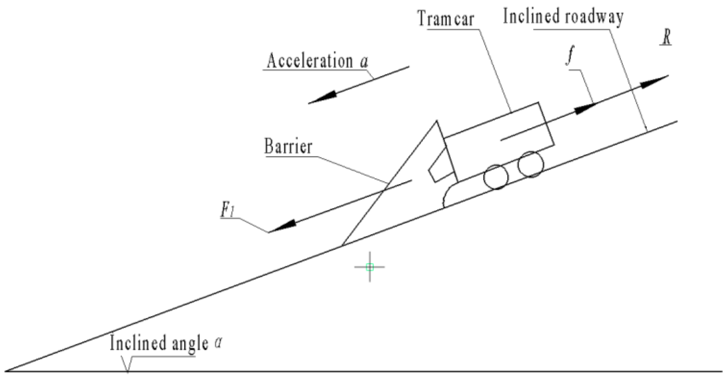


Figure 2. Buffer Model, Stress Reduction

In the roadway along the inclined direction, the buffer and the car as a whole force, by mechanical knowledge:

$$F_1=R \tag{10}$$

When the buffer is balanced by the active force and the braking force and the friction force, the (7) (8) (10) (9) is merged, and the

$$F_1= G\cdot sin\alpha\text{-}u\cdot mg\cdot cos\alpha \tag{11}$$

(2)Energy absorbing energy of buffer braking process:

$$E=mgL[sin\alpha - \omega cos\alpha]\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(12)$$

Where E is the kinetic energy of the object at the initial moment of braking: MJ;v_0 is the instantaneous speed of the braking moment of the object is 25.6m/s;ω is the resistance coefficient in operation of cars, take the Omega =0.02; L is the stopping distance: L=60m.

(3)Calculation of braking force required for vehicle:

Consider roadway inclination angle and braking stability of bucket and bucket box under the maximum braking resistance ability, the primary role to skip the minimum braking resistance:

$$R_{min}= mg\,[sin\alpha - \omega\cdot cos\alpha + j/g\,]\ \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(13)$$

Where α is the inclination of the roadway; α is the dip angle is generally less than or equal to 40 degrees;g is the gravity acceleration 9.8 m/s^2;ω is the resistance coefficient in operation of cars, take the Omega =0.02;j is the artificially set braking deceleration;m is the total quality under full load: 16000kg.

3. Flexible Buffer Simulation

By understanding the actual, the Scotch bar in practical application for the flexible buffer system by the maximum impact force components, so for the Scotch bar were dynamics simulation is necessary, In order to establish the solid model and dynamic simulation of tramcar flexible buffer, UseUG8.0 the establishment of 3D model of tramcar high-energy collision flexible buffer barrier, Will build the model import MSC.ADMAS 2014, Add a deputy campaign to applied loads and constraints, and solve and analysis showed that dynamics simulation test of tramcar and flexible bumper design rationality. Using MSC.ADMAS 2014 to carry out the dynamic simulation analysis steps as shown in Figure 3 [8].

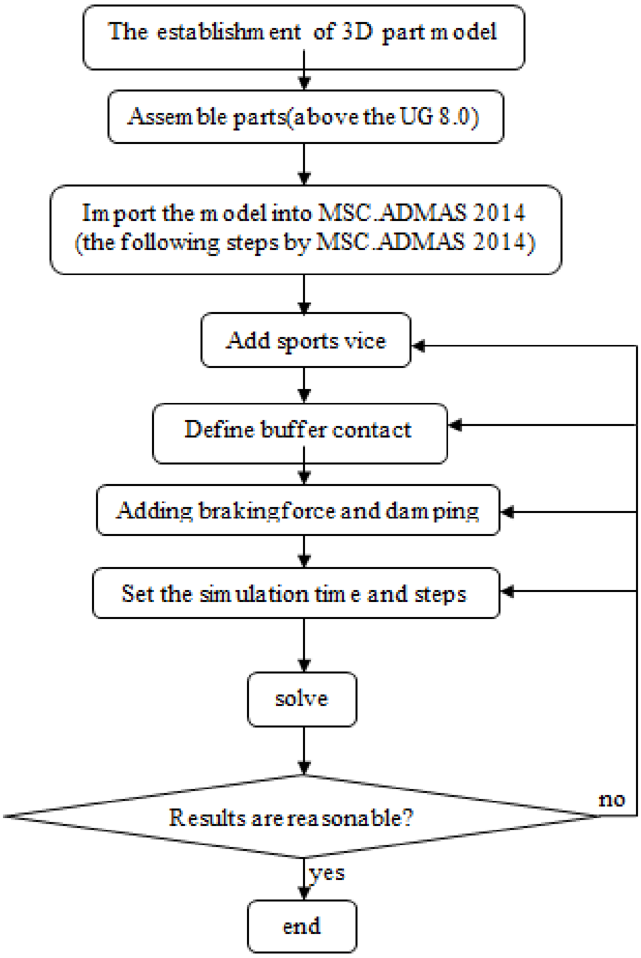


Figure 3. MSC.ADMAS 2014 for Dynamic Simulation Analysis Steps

3.1. The Use of UG 8 on the Car and the Flexible Buffer Modeling

Through the actual size in UG 8.0 respectively established Scotch bar model of flexible buffer parts. After the establishment of the parts model is completed through the constraint conditions of general assembly, as shown in Figure 4 for the assembly drawing of the moment of collision.

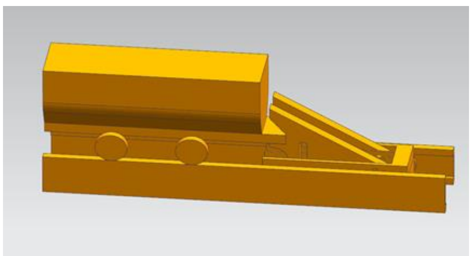
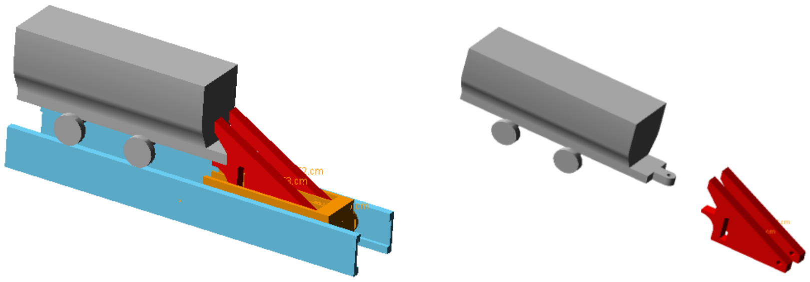


Figure 4. Assembly Collision Tramcar and Flexible Bumper

3.2. MSC.ADMAS 2014 Dynamic Simulation Analysis

(1)Model simplification

General car 2-8 range, its overall quality is not greater than 16000KG here will simplified model. The car was established as a model, but overall quality reached maximum, the pulley and a brake system, the system model and the horizontal direction to maintain 30 degree angle. Before and after simplification model as shown in Figure 5.



(a) Simplify the Former Model (b) Simplified Model

Figure 5. Simplification of the Model

(2)Analysis model before processing

The establishment of dynamic simulation model, do the following settings:

1) the acceleration of gravity is -9.8m/s2;

2) and the brake pulley and the earth is sliding direction and the direction of the slope side;

3) contact between the pulley and the brake;

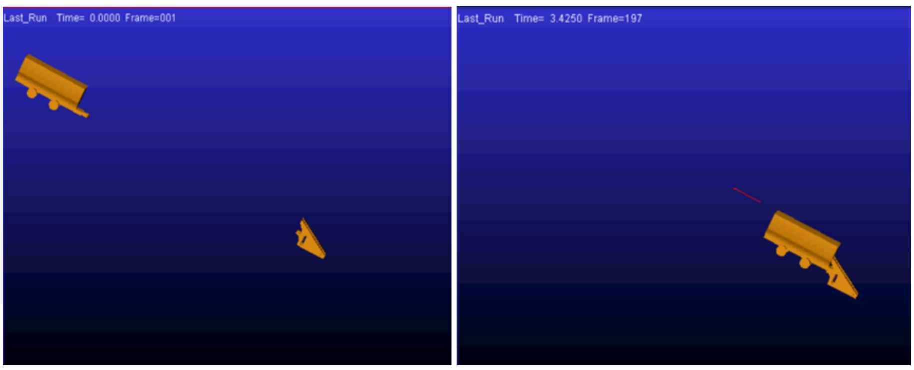
4) the sliding friction coefficient is 0.2;

5) the damping of the brake movement direction is 40N.S/mm;

6) skip the total quality of 16000kg at full load。

(3)Dynamic simulation

Set the simulation time is 35S, the simulation step number is 10, through the simplified model to simulate the dynamic simulation of Figure 6 for the simulation of the collision moment of the braking distance is about 7.5m, as shown in Figure 8, 1000KN.



(a) Before the Car Crash Barrier State (b) After the Car Crash Barrier State

Figure 6. The Car Hit the Barrier around the State

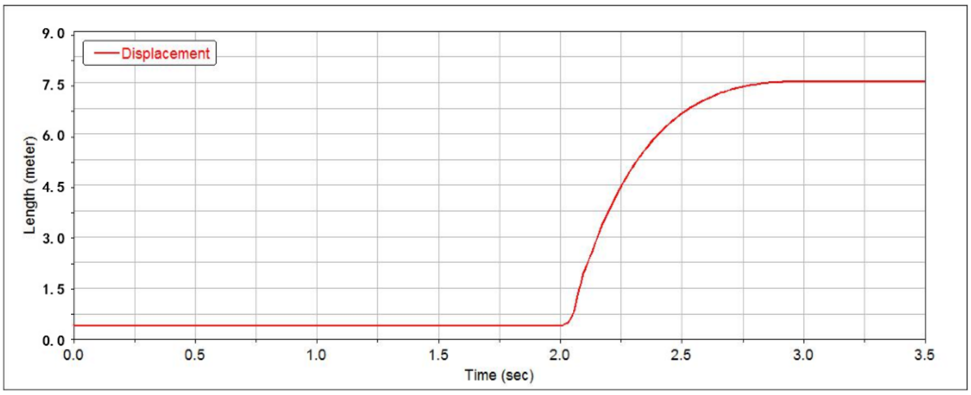


Figure 7. Relationship Chart of Braking Time and Displacement of Flexible Buffer

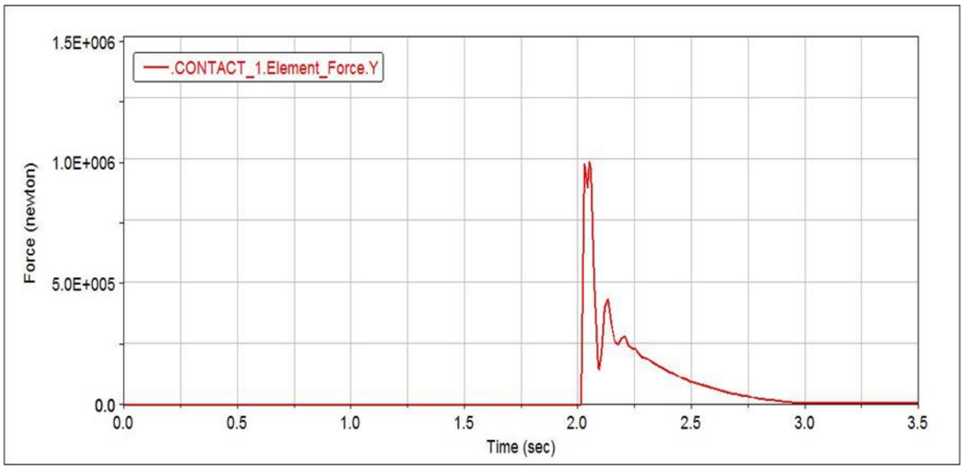


Figure 8. Car Barrier Impact Force Moment of Flexible Buffer

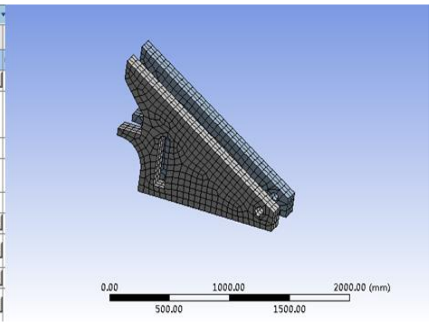
(4)ANSYS Workbench 15 finite element analysis barrier

Prior to the adoption of mechanical model, we can conclude that, at the moment of collision Scotch bar subjected to impact force is great, we put mine regarded as rigid body, extraction barrier model for mechanical finite element analysis, by means of mechanical analysis and check Scotch bar is under the huge impact realize the cycle of repeated use.

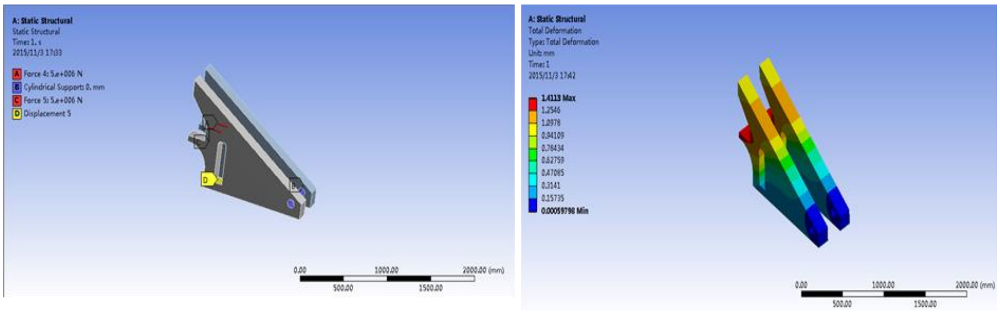
First, the extraction of Scotch bar model into ANSYS Workbench 15.0, definition of barrier materials, there will be the setting for steel materials, the next step into mechanical interface is provided with a contact of Scotch bar and Mesh applied constraints and solution, the above steps as shown in Figure 9.

Properties of Outline Row 3: Structural Steel

	A	B	C
1	Property	Value	Unit
2	Density	7850	kg m^-3
3	Isotropic Secant Coefficient of Thermal Expansion		
6	Isotropic Elasticity		
12	Alternating Stress Mean Stress	Tabular	
16	Strain-Life Parameters		
24	Tensile Yield Strength	2.5E+08	Pa
25	Compressive Yield Strength	2.5E+08	Pa
26	Tensile Ultimate Strength	4.6E+08	Pa
27	Compressive Ultimate Strength	0	Pa



(a) The Definition of Barrier Materials (b) Schematic Diagram of Barrier Grid



(c) Schematic Diagram of the Blocking Constraint Se (d) The Blocking Column Overall Column Deformation Nephogram

Figure 9. ANSYS Workbench 15.0 Finite Element Analysis Sequence Diagram

Workbench ANSYS 15 finite element analysis sequence diagram through before Section 2 mechanical model we can come to the dynamics and finite element analysis data, the kinetics can be seen when the car is fully loaded, downward along the track movement, the impact Scotch bar moment for maximum impact force, prior to the dynamics analysis of the maximum impact force, the Scotch bar were finite element analysis, that Scotch bar at the moment of impact deformation of 1.4mm deformation rate was 0.12% metal generally will have a rebound, has little effect on the follow-up work of the Scotch bar can be used repeatedly in order to reduce the cost.

4. Buffer Design and Application

Composition of high-energy collision flexible buffer includes not only the blocking column including: brake transmission buffer, speed measuring device, electric control box, monitor display box, monitor background etc monitoring display box is connected with the touch screen, you can monitor the working condition of car stopping device. Device with remote procedure setting, modify and restore remote control function, can realize remote equipment debugging, remote maintenance and update technology. Multi buffer damping force, the flexible adjustable step by step, energy absorbing structure, buffering and absorbing energy, stable, safe and reliable. When a carriage accident on the roadway, car damage degree is extremely low, truly achieve the purpose of buffering, for all inclined roadway anti slipping protection to provide comprehensive solutions. The basic components of car intelligent protection device structure as shown in Figure 10, a coal mine car high energy collision flexible buffer track design is shown in Figure 11.

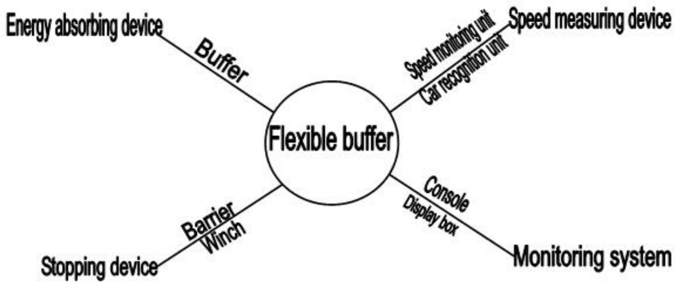


Figure 10. Coal Mine Tramcar High-Energy Collision Flexible Buffer Composition Diagram

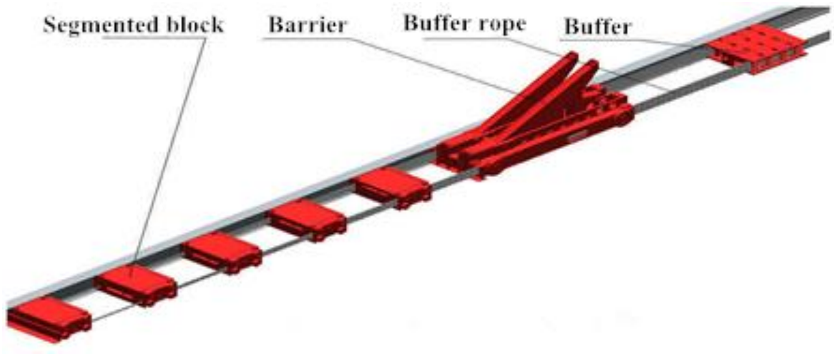


Figure 11. Coal Mine Tramcar High-Energy Collision Flexible Buffer Track Scenograph

In the inclined mine car transport, due to the wrong workers carelessness or method of operation will cause the belt rope car illegal discharge gate speed and operation with improper loosened ropes shock, did not carefully check wire rope broken caused by the rope, such as car accidents, causing serious casualties and economic losses to the safe production of coal. [9] Therefore, installed in the inclined transport tram in flexible reducer is extremely important safety facilities in mine safety production, the installation of the inclined rail, will be able to run the vehicle stop or interrupt rope hook in mine car running on the track. Although the protective equipment used in inclined tunnel transportation long has many kinds, but in order to make the protective device can adapt to the complex environment and the mine action is accurate, sensitive and reliable, low cost, strong anti-interference ability, simple structure in one, accurately stop inclined transportation interruption rope or vehicles need decoupling, continuous study and exploration developed a new type of protective equipment more perfect, so the coal mine the tramcar high-energy collision flexible buffer emerge as the times require. When the speed measuring device detect car out of control, signals are transmitted to the monitoring system, monitoring system of can device and Scotch device under the instruction, the timely stopped the mine car out of control. And coal mine inclined shaft runaway car collisions flexible buffer in practical applications with high security and intelligence can, in the future production and processing can not only improve the safety of the production line and the liberation of human intelligent control, so as to improve the economic benefit.

5. Peroration

（1）Through mechanical modeling, analysis of the coal mine inclined shaft runaway car collisions flexible buffer in mine car out of control by force, and pave the way for the later simulation analysis.

（2）By using UG 8, MSC.ADMAS 2014 and Workbench ANSYS 15, it can be used to analyze the whole and the stress of the flexible buffer effectively, so that the design time and reliability can be improved obviously.

（3）Mechanics modeling, dynamics analysis and finite element analysis to pave the way, can fully and reasonably to design of coal mine inclined shaft runaway car collisions flexible buffer, save a lot of design cost and time.

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