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Numerical Simulation on Shock Failure Characteristics of Pipe Surface with Different Radii under Gas Explosion

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Abstract

In order to obtain the failure characteristics of pipe surface under the shock wave action of gas explosion, the physical and mathematical model of gas explosion in pipe were established by LS-DYNA software, and the shock failure characteristics of pipe surface with different radii under gas explosion were simulated, the radius is 0.4 m, 0.6 m, 0.8 m and 1.0 m, respectively. Results showed that with the increase of the radius, the duration of the pressure "platform" in the measuring point A and B is obviously shortened, fluctuation range produced by the pressure curves in measuring points C, D, E and F change less, but their fluctuation time is shortened. The explosion pressure increases and the failure degree increases with increase of the radius. Finally, the influence of scale effect of gas explosion and its propagation process on gas explosion propagation parameters is obtained. The research results have some guiding effects on gas explosion and disaster prevention.

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Keywords: gas explosion, failure characteristics, explosion strengths, numerical simulation, pipe surface

1. Introduction

Gas explosion in coal mine is one of the most serious disasters during coal mining, especially, the major gas explosion accidents result in many casualties, huge property losses and serious damage to the facilities and equipments, which brings bad social effect, for example, gas explosion accident in Daping coal mine in 2004, gas explosion accident in Chenjiashan coal mine in 2004, gas explosion accident in Sunjianwan coal mine in 2005 and gas explosion accident in Ruizhiyuan coal mine in 2007, etc. Therefore, the Chinese government has increased the safety input and strengthened safety management of coal mines, the mechanized mining technology was introduced in state-owned key coal mines, the proportion of which has reached 75%. A large number of laws and regulations were promulgated and revised to strengthen safety management, such as “coal mine safety regulations”, “prevention and control of coal and gas outburst”, etc. At the same time, small coal mines of incomplete documents and illegal exploitation were resolutely banned. The safety technology and management level of coal mine in China has been greatly improved; the safety production of coal mine in China continues to be improved. However, many gas explosion accidents happen occasionally. For example, gas explosion accident in Xiangyang coal mine in 2015, gas explosion accident in Qitaihe coal mine in 2016. Many experts and scholars have carried out a large number of experimental studies on gas explosion by experimental roadway or pipe platform [1-5], some scholars have adopted the numerical simulation method to analyze the gas explosion and obtained a lot of research results [6-9], for example, mechanism and propagation law of gas explosion, influence factor, impact failure characteristics, mechanism and technology of gas explosion suppression. However, in some mines, shock waves of gas explosions even can damage ground personnel and buildings through the roadway [10-12]. Therefore, scholars always pay great attention to the shock failure of the surrounding structures under the impact of shock waves, and have carried out a lot of researches [13-15]. The gas explosion propagation law in pipes with different diameters was also studied; it was found that the pipe diameter has a great

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influence on the gas explosion strength, pressure and propagation velocity [16, 17], the impact characteristics and failure laws are obtained. However, the analysis on surface failure characteristics of pipes with different radii is less. LS-DYNA can well solve the problem of surface failure caused by thermal impact. Therefore, numerical simulation of thermal shock failure caused by gas explosion in pipes with different radii is carried out by using LS-DYNA. As the main component of mine gas is CH_4, CH_4 is elected as explosion gas in this paper to carry out the simulation and theoretical analysis. The research results are expected to provide theoretical basis and technical guidance for the prevention and control of gas explosion accidents in the confined space such as coal mine or gas tunnel, as well as for the reduction of the gas explosion disaster losses.

2. Establishment of physical and mathematical model

2.1. Physical model

2.1.1. Establishment of finite element model

The unified system of units (kg/m/s) of model and parameters of the materials are adopted in this numerical simulation. The geometric parameters of the pipe are adopted in this numerical simulation as follows, the length of pipe is 20 m, the radius is 0.4 m, 0.6 m, 0.8 m and 1.0 m, respectively. One end is closed, another end is open. The pre mixed gas is separated by a diaphragm at the open end of the pipe; the finite element model of the pipe is shown in Fig. 1. In the direction of Z axis, A (0, 0, 2) is the starting point, the measuring points B, C, D, E and F are arranged with equal interval of 3 m.

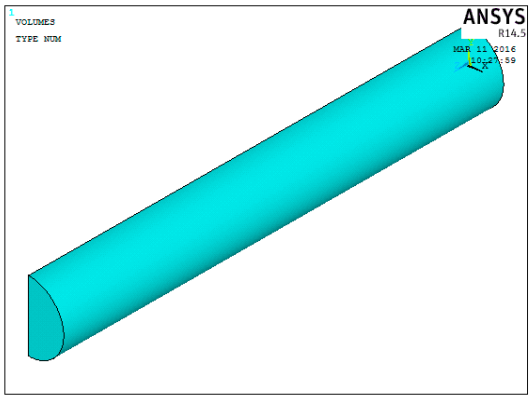

Fig. 1. Finite element model of pipes

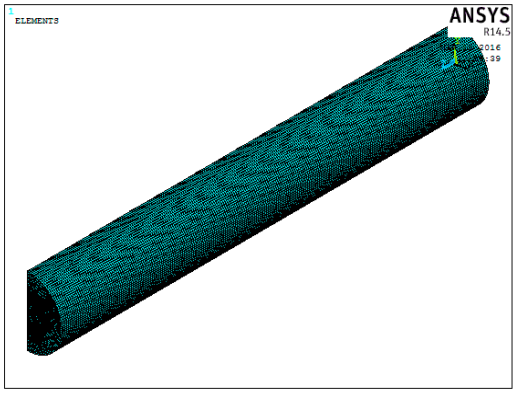

Fig. 2. The finite element model after mesh generation