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Conventional and numerical models of blasting gas behaviour in auxiliary ventilation of mining headings

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ABSTRACT

A study has been carried out in a coal heading, excavated by drilling and blasting in a deep underground mine located in Northern Spain (Hullera Vasco Leonesa S.A.), by measurements of blasting gases, CO and NO_2, in three cross-sections of the heading located at 20, 30 and 40 m from the heading face.

Mathematical models of gas dilution, according to the dilution time after blasting, have been developed. These models show the differences between the obtained values by application of these experimental models and the values of other mathematical model in common use.

The mentioned differences indicate the need to obtain in each underground work its own dilution models of blasting gases. This need is more important when the mass of explosives, the cross sectional area of the heading and the conditions of the auxiliary ventilation keep away from the ones used in order to obtain the mathematical model in common use.

4D models have been developed by Computational Fluid Dynamics (CFD) through software Ansys CFX 12.0. The CFD model results have been validated and compared to experimental models obtained in the measurement programmes.

From these CFD models other dilution behaviour mathematical models of blasting gases can be developed for other cross sectional areas, other mass of explosives and other ventilation parameters.

The experimental mathematical models and CFD models obtained allow us to analyse how the blasting gases behave and therefore to know in which conditions it is safe for the workers to return to a blasted area.

1. Introduction

When drilling and blasting method is used in underground development headings, toxic gases, CO and NO_2, are released (ISEE, 1998; Mainiero et al., 2007).

The safe re-entry of miners in the heading face and the rest of the mine depends on the gas concentration contained in the plug and that its dilution by the auxiliary ventilation airflow reaches a value below the threshold limit value (TLV) set by regulations (McPherson, 1993; Gherghel, 2010; Hine and Jones, 1985).

Time weighted average (TWA) and threshold limit values of exposure time established by Spanish regulations are TWA of 50 ppm for CO and 10 ppm for NO_2 and short term exposure limit (STEL) of 100 ppm for CO and 25 ppm for NO_2 (ASM-2, 1985).

It has been proved that current dilution mathematical models involving blasting in underground mining practices (Skochinsky and Komarov, 1969; De Souza and Katsabanis, 1991; Howes, 1983; Gillies et al., 2004) are appropriate when the cross sectional area, auxiliary ventilation system and mass of explosives used are close to characteristics of the tests conducted from which the mentioned models have been obtained.

The first aim of this research has been the development of appropriate mathematical models of gas dilution for a heading of small cross sectional area and when small amount of explosives are used. This is of great importance in both underground coal and metal mines and other underground operations.

From the possible control measures against blasting gases (Hartman, 1992): dilution, prevention, extraction, isolation and containment, the most current measure, dilution, has been studied by means of auxiliary ventilation.

Likewise, when conventional methods are used to calculate auxiliary ventilation, the results are poor since they are based on the determination of airflow and pressure values in a fixed instant and for an unique point of an unique section of the underground work (Onder and Cevik, 2008; Suglo and Frimpong, 2001; Toraño et al., 2002; Likar and Cade, 2000).

It is necessary the analysis of auxiliary ventilation by means of 3D, computational methods taking into account time (4D) and

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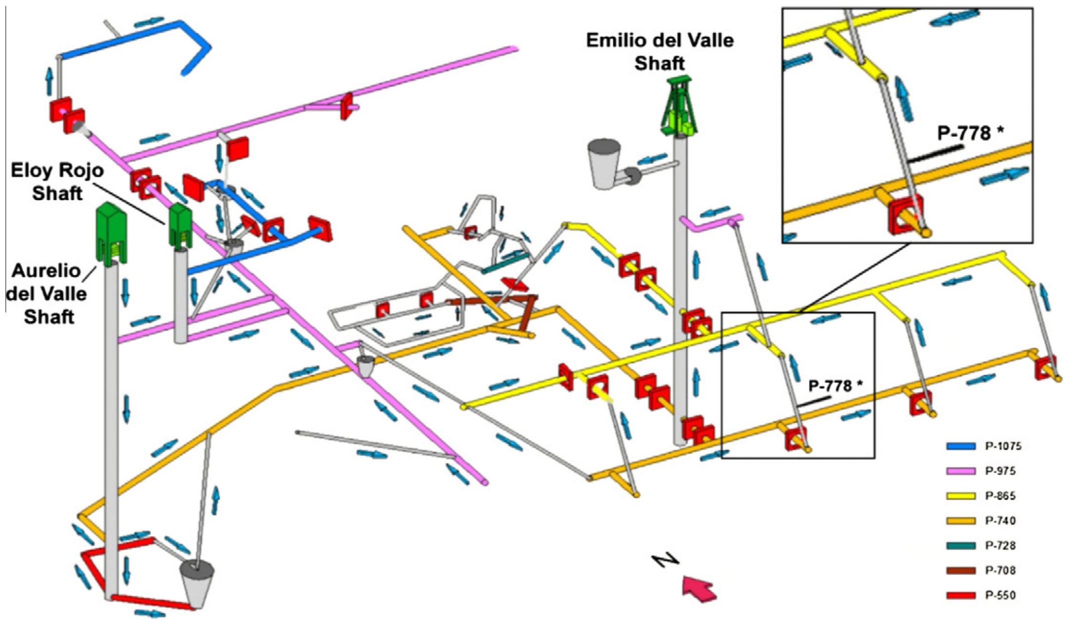

Fig. 1. Main ventilation network of the underground coal mine.

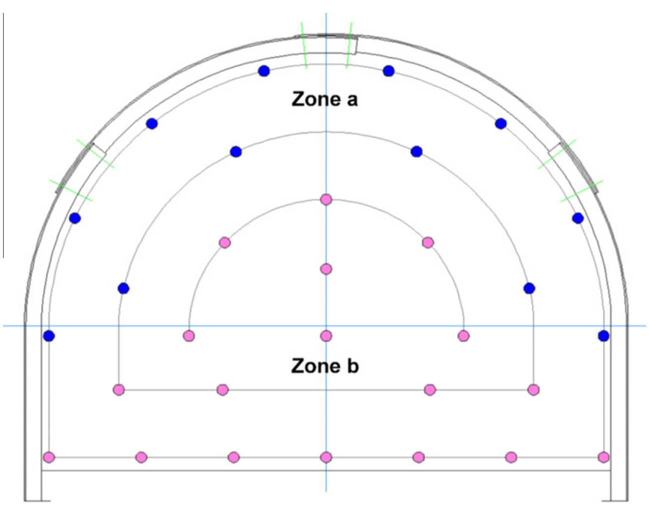

Fig. 2. Sketch of the blast.

Table 1
Altair 5*x* specifications.

Blasting gases	Sensing range	Precision
Oxygen O_2	0–30 vol.%	0.1 vol.%
Carbon monoxide CO	0–2000 ppm	1 ppm
Nitrogen dioxide NO_2	0–20 ppm	0.5 ppm
Carbon dioxide CO_2	0–10 vol.%	0.01 vol.%

validating these models by measurement programmes (Moloney et al., 1999; Moloney and Lowndes, 1999; Parra et al., 2005; Toraño et al., 2006, 2009, 2010; Wala et al., 2003; Yuan et al., 2006).

The second aim of this study has been the development of 4D models of gas behaviour by Computational Fluid Dynamics (CFDs) through software Ansys CFX 12.0 (2009). The CFD model results have been validated and compared with experimental measurements and then the CFD model results have been successfully compared to the mathematical models developed in this study.

Based on these CFD models, validated by experimental measurements, other dilution behaviour models of blasting gases, can be developed for other cross sectional areas, other mass of explosives and other ventilation parameters.

These mathematical models and CFD models represent powerful tools to be able to analyse how blasting gases behave and to know when and in which conditions workers can return to the blasted area.

2. Underground airflow and blasting toxic gas measurements

Hullera Vasco Leonesa S.A. Company is located in the province of Leon in the North of Spain. The annual coal production is 2 million tons and the proved exploitable coal reserves at the end of 2011 are 45 million tons. The Pastora coalbed varies in thickness

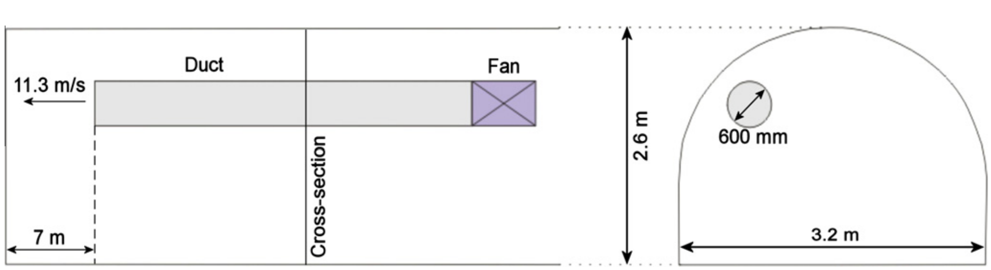

Fig. 3. Sketch of forcing ventilation system.