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Mitigation of air leakage through the goaf of retreat coalfaces

Christian Tauziède, Zbigniew Pokryszka - Institut National de l'Environnement Industriel et des Risques (INERIS) (France)
Pierre Schroeter, Pierre-Marie Dupond - Houillères du Bassin de Lorraine (HBL) (France)

Abstract

In HBL (Lorraine coalfield), large amounts of air are used in order to dilute methane in retreat coalfaces. A parasite flow of air exists in the goaf, leading to the risk of spontaneous combustion of remaining coal as well as to a diminution of firedamp drainage efficiency. The evaluation of various means for reducing this flow has been done through the use of models : a physical model and a numerical model based on a CFD package. The efficiency on air leakage reduction, decrease of methane concentration in the air return or increase of methane concentration of drainage has been quantified for one or more stoppings set up in the abandoned gates or for their backfilling. The influence is small but positive as regards drainage efficiency improvement but almost zero on risk mitigation of spontaneous combustion in the goaf.

Foreword

The Lorraine Coalfield mine coal by longwall in retreat coalfaces. The seams are thick (from 3.5 to 4.5 m) and prone to relatively high firedamp emission (the dissolvable concentration of coal to methane ranges from 4 to 10 m^3/t, and the specific discharge from 20 to 50 m^3/t). Unitary productions are high (from 4,000 to 6,000 t/day), thus, the implementation of large quantities of air is required. The ventilation of these coalfaces is performed according to the traditional retreat coalface scheme, i.e. according to a U: air intake by bottom gate and air return by tail gate. After the face passage, these accompaniment roadways are not upheld. Air flows usually implemented on sites range from 30 to 60 m^3/s, and allow to sufficiently dilute firedamp in order to observe the statutory limit concentrations in the face air return. To this regard, firedamp drainage is also nearly systematically performed.

Unfortunately, a part of the district air flow is deviated towards the goaf, concurrently to the air circulating in the coalface, as the goaf constitutes a porous and permeable medium. The air leakage rate is defined as the ratio between the air flow going through the goaf and the district total air flow. This ratio changes from one site to the other, mainly according to the type of strata constituting the roof of the mined seam, and to the land's pressure. Indeed, many on-site measurements performed with tracer gas (SF_6 - sulphur hexafluoride) allowed to establish leakage rates ranging from 10 to 30%, and sometimes reaching 35%! A simple calculation allows to acknowledge the importance of the air flow circulating in the goaf: for an air flow of 50 m^3/s and a leakage rate of 30%, which is quite a common situation, an amount of 15 m^3/s of air flows through the goaf.

Although this flow contributes to firedamp dilution on the district as a whole, nevertheless, it represents a problem, which can become critical for certain faces, for at least two reasons:

- the first problem comes from the fact that this parasitic flow interferes with the firedamp drainage that is usually directly performed in the panel, at the high point of the face start-up line (drainage chamber method). The parasitic air reduces the methane concentration in this area, sometimes to the extent that any drainage becomes impossible, and can hinder the furtherance of the working;

- the second problem, which is maybe the most important, comes from the fact that coal from these coalfield is particularly subject to spontaneous combustion. There is always a more or less large quantity of coal in the goaf, either because it was abandoned to the roof of the mined seam when it is too thick, or because it comes from a close-by satellite coal seam.

Parasitic air flows, whether in the part of the panel which is already exploited, or in an already mined neighbouring or superior panel, can create favourable conditions for coal heating: oxygen inflow and lack of heat discharge. It is difficult to control such a situation and it can lead to an incident, if not a serious accident, linked to firedamp ignition for example.

Model development

As of 1990, Charbonnages de France ordered research from INERIS to study gas circulation in the goaf and to find means to fight the existing hazards, as well as answers to the problems mentioned above. Although still underway, these research projects led to the design and development of flow models. A physical scale model, and a computerised numeric model grounded on the use of a Computational Fluid Dynamics package. Then very concrete results were obtained thanks to the practical use of these models, pertaining to the establishment of optimum firedamp drainage parameters, as well as to the optimisation of nitrogen injection in the goaf to prevent the occurrence of coal spontaneous combustion in such areas [Tauziède et al. 1993; Pokryszka et al. 1997].

Results mentioned in the present paper concern the search for ways of reducing global leakage of parasitic air flow through the goaf. However, a brief presentation of the two available models is previously performed.

Firstly, as regards the physical model, it is a $1/70^{th}$ scale model, developed jointly with the Institute of Occupational Medicine in Edinburgh (Scotland) [Jones et al. 1997]. The similarity factors were carefully established in order to guarantee that flows are identical to those which exist in a real coalface. To that end, the model was reversed, SF_6 replacing methane. This gas is injected and distributed in a non-uniform way in the model. The distribution of granular materials representing the waste is not uniform either, in order to take into account spatial variations, which exist in reality, because of the non-homogeneous re-compaction of the strata in the goaf.

As regards the numerical model, it was developed based on the PHOENICS "CFD package", to which fluid dynamics equations ruling flows, whether in a free medium or in a porous medium, were integrated [Tauziède et al. 1993].

Numerous on-site tests and measurements were conducted to qualify and quantify the influential parameters, and to set the two models on different real coalface configurations [Pokryszka 1995].

The results obtained by operating one or the other of the two models on a specific case, come in the form of gas concentration spatial distributions (methane, air, and possibly nitrogen, if this gas is used to make the goaf inert). Therefore, the efficiency of a specific mean as regards the behaviour of these gases can easily be assessed. Models were used to optimise firedamp drainage and to make the injections of nitrogen as efficient as possible to prevent or fight coal combustion[Tauziède et al.

1997; Pokryszka et al. 1997].

Modelling of the treatment efficiency of the roadways in terms of reduction of air leakage through the goaf

Results mentioned in the present paper pertain to the comparison of the influence of various treatments envisioned in the face gates. Indeed, these roadways which are abandoned after the face passage are often a privileged vector for a parasitic air flow in the goaf. The idea is to reduce the general air flow circulating in this medium. Therefore, the prime objective of these treatments is to improve drainage efficiency because of a weaker firedamp dilution by the parasitic air. The second objective consists in improving natural goaf inerting, also due to the presence of firedamp at higher concentrations.

Therefore, specific modellings were performed to assess the compared efficiency of:

- stoppings, in one or the other gates, behind the face, or in the two roadways at the same time;
- or backfilling of these galleries.

Modelling on scale model

As regards modellings performed on the scale model, they pertained to two different coalface configurations, with one or several stoppings set up in the tail and/or bottom gates: stoppings located immediately behind the face for bottom gate or tail gate, 3 or 4 approximately regularly distributed stoppings along the bottom gate. The face which was subject to simulations had the following characteristics:

- face length: 240 m;
- face progression from its start-up line: 260 m;
- air leakage rate: 25% (case No. 1) or 16% (case No. 2);
- air flow: 31.5 m^3/s (case No. 1) or 50 m^3/s (case No. 2);
- methane drainage flow: 0.3 m^3/s;
- nitrogen injection flow: 0 (case No. 1) or 0 or 2,000 m^3/hr (case No. 2).

Figure 1 shows the results of these models.

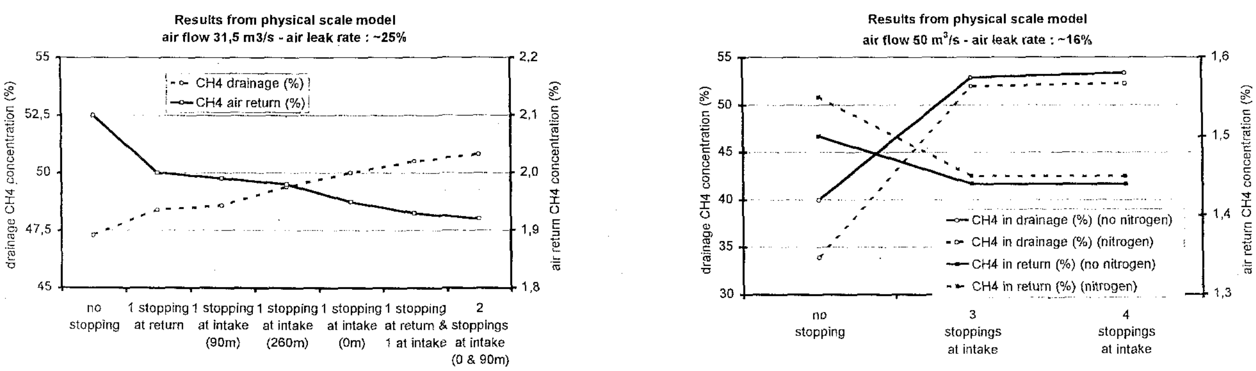


Figure 1 : Results from physical modelling

These results are expressed in terms of methane concentration in the air return and methane concentration in drainage. Compared to the reference situation on the left-hand side of each graph, the following comments should be highlighted:

- for case No. 1 (31.5 m^3/s air flow), one can note the effect of a stopping or of two stoppings together. A stopping located on the air intake side is more efficient than a stopping on the air return side. The highest efficiency is obtained with two stoppings along the abandoned air intake roadway;
- for case No. 2 (50 m^3/s air flow), one can note the influence of 3 or 4 stoppings in the abandoned air intake roadway when there is no nitrogen injection (continuous lines) or when there is an injection of nitrogen (dotted lines).

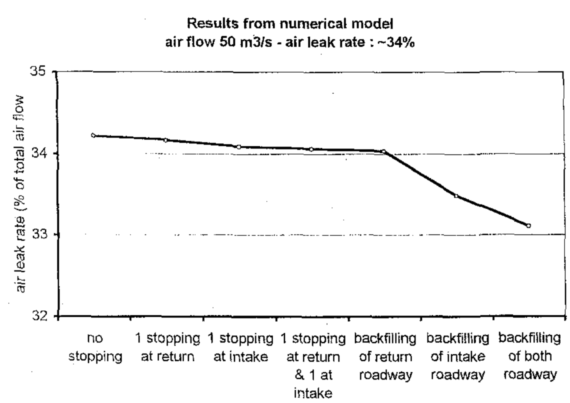
Numerical modelling

With the numerical model, simulations were performed on a face geometry very similar to that of the scale modelling. The case of a stopping at air intake and/or at air return was tested, as well as those corresponding to a full backfilling of the air return and/or intake roadway. The following numeric values were used:

- air leakage rate: 17% or 34%;
- air flow: 36 m^3/s or 50 m^3/s;
- methane drainage flow: 0 or 0.45 m^3/s;
- nitrogen injection flow: 0.

In figure 2, results are expressed in terms of air leakage rate through the goaf, which allows direct evaluation of the effect of treatment simulated.

The strongest leak rate reduction is observed with the backfilling of one or, even better, the two abandoned roadways. This improvement is mostly significant when the air leak rate is high, as shown on the bottom graph.



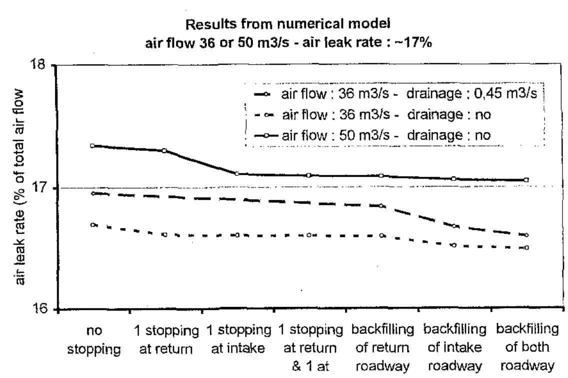


Figure 2 : Results from numerical modelling

In the event that firedamp drainage is performed, the reduction in the air leak through the goaf leads to a reduction in methane concentration in the air return (figure 3).

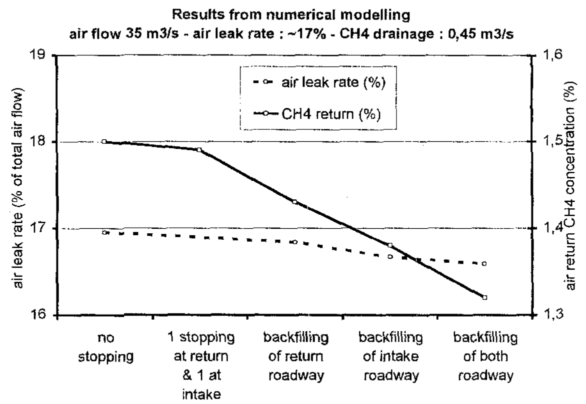


Figure 3 : Results from numerical modelling (continuation)

In both simulated cases, results are coherent with those obtained from the scale model, i.e.:

- the efficiency of a treatment on an abandoned air intake gate is higher than a treatment on the abandoned return gate;
- full backfilling of one or the two roadways is more efficient that simple stoppings.

Results analysis

However, these two series of tests and simulations highlight that the obtained results, i.e. the efficiency of the implemented means, remain rather disappointing. Indeed, in the best simulated case, the relative decrease in methane concentration in the return roadway is only of ca. 8%. This reduction in concentration on the air return, obtained by an improved goaf tightness, constitutes a significant improvement as it allows improving firedamp drainage, even if only slightly.

Therefore, expansion foam stoppings are systematically implemented in the abandoned air intake and air return roadways of all faces of Lorraine Coalfield. Sometimes, the full backfilling of the abandoned air intake roadway is performed. Therefore, the prime expected objective of these treatments is partly achieved.

Unfortunately, the second objective of abandoned roadway treatment, i.e. improvement of natural goaf inerting, is not achieved. Indeed, these stoppings or backfillings do not allow significantly to reduce air leakage rate in the goaf, under the studied conditions. In most cases, notably when the leakage rate is very high, the concentration in oxygen remains high enough for coal self-heating. To prevent this, it is often necessary to perform massive and continuous injections of nitrogen in the goaf in critical cases. Very heavy means, such as massive injection of backfilling in the waste would be required to significantly reduce the parasitic air leakage through the goaf. However, the implementation of such solutions raises major technical and economic problems.

Perspectives

In spite of the relatively slight results mentioned above, a positive conclusion to the use of these models can be drawn. The development of these tools was a long and rather tedious task which took place over several years. However, they provide a significant help to analyse the effect of specific means to fight against firedamp or spontaneous combustion. Therefore, they contribute to the improvement of collective safety of the workings. More specifically, the numeric model has a high versatility and can be adapted to all configurations, notably geometric. Thus, it is superior to the physical scale model.

Evidently, these models will still be subject to many developments in the future, as it is already the case today in several coal producing countries.

Credits

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