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FOG MESH STUDIES FOR FOG REMOVAL

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Abstract

Field tests concerning a fog mesh method for fog removal are discussed. The first tests were performed at the Pyhäsalmi Mine, Finland. As this study gave promising results, further studies were completed at the Orivesi Mine.

The results of these most recent field tests are presented and the two studies are compared. The Orivesi test set consisted of four materials. These included air filter fabric, fibrous filter fabric, a plastic greenhouse mesh, and an aluminium mosquito net.

The variation of the Orivesi results was more noticeable than what was found previously. The best fog removal effect of all tests was achieved with the aluminium mosquito net, while the plastic greenhouse mesh performed worst.

The humidity reduction by aluminium net was more profound than any of its precedents. More mesh materials will be tested in the near future.

Introduction

In a previous article by Martikainen (2007) the fog mesh method for fog removal was introduced. The theory of fog removal by the mesh fabric was presented, field tests were demonstrated, and the results, and result analysis were given. The feasibility of the method was considered in detail. Also, the use of mesh fabric as a water collector in arid regions was discussed briefly for comparison purposes and to show the practicality of the approach.

At the conclusion of that article some questions remained. The optimal mesh material had not yet been identified. It was also considered important for the studies to be completed in another mine with different conditions. In this paper, studies that refer to these issues are presented.

This study consists of a similar set of on-site measurements as described in the article ”Fog mesh as an alternative fog removal method in mine ramps”. These tests include air velocity, air temperature, dew point temperature, particle concentration, and relative humidity measurements as well as observations with each mesh material. The tests were conducted at the Orivesi Gold Mine in Finland. The ventilation system of the Orivesi Gold Mine is discussed more thoroughly in Martikainen (2006a). Of the four different tested mesh materials, one was also used in the previous research setting at the Pyhäsalmi Mine.

Field Test Procedure

Test Site Considerations

First a location for the field tests was selected. Based on the conclusions of the Pyhäsalmi mine study, a site with different airflow characteristics was sought in the Orivesi mine. The test site selected is thus at a different depth and has dissimilar psychrometric conditions. Another important difference is that at the Pyhäsalmi Mine, all measurements were performed during operation, while Orivesi Mine was in a standby mode.

The chosen site for these tests was in the decline a short way below level +164 m. Due to the mine’s standby situation, the air was expected to be cleaner and to have fewer airborne particles and aerosols. Due to these factors, it was assumed that fogged air would have higher relative humidity, lower particle concentration, and larger droplet size.

A similar frame setting was built for the fog mesh as that built at the Pyhäsalmi Mine. The structure of the frame is shown in Fig. 1. Because of limited supply of two of the materials, this frame was built first with a larger opening for the first two materials and then narrowed for the remaining two. The height and width of the openings were 3.8 m by 4.6 m, and 3.8 m by 3.9 m for the larger and smaller openings, respectively. Baseline measurements without a mesh were taken with both opening widths for comparison purposes.

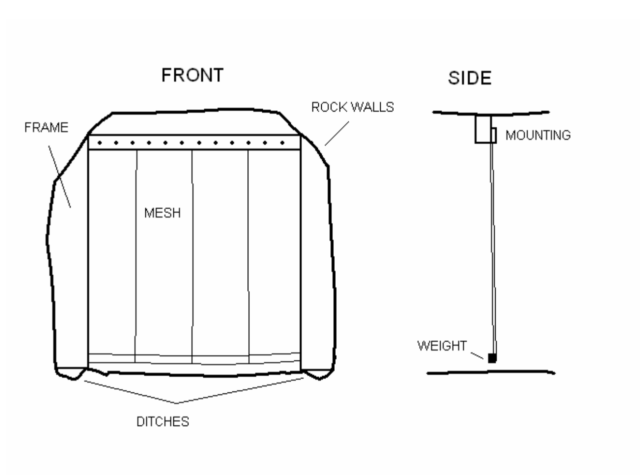

Figure 1. Fog mesh frame structure. (Martikainen, 2007)

Measurements

Air velocity, relative humidity, air temperature, dew point temperature, and particle concentration were all recorded. Also, subjective observations were made concerning fog thickness, fog droplets, and the effects of the meshes on the airflow. To enable easy result comparison, tests were performed 50 m apart, 25 m upstream and 25 m downstream of the mesh, as was the case for the Pyhäsalmi measurements.

Air velocity and temperature measurements were performed with a hot wire anemometer, model Kimo VT200. The measurement range of the anemometer is from 0 m/s to 40 m/s of air velocity and from -100 °C to +400 °C of temperature. The precision of air velocity measurements is 0.01 m/s and the precision of temperature measurements is 0.1 °C. The accuracy of air velocity value is ±3 % ±0.03 m/s of the reading and the accuracy of the temperature value is ±2 % ±0.1 °C of the reading.

Humidity measurements and verification air temperature measurements were done with an Ebro TFH100 hygrometer, which measures relative humidity of 0 - 100 per cent and temperatures from -10 °C to +80 °C. The resolution of the instrument for relative humidity is ±0.1 %. The accuracy of the relative humidity, temperature and dew point temperature measurements are ±2 % of the readings.

An aerosol meter, DustTrak TSI 8520, with a maximum particle size range of 0.1-10 µm was used for dust content measurements. The aerosol meter has a measuring range of 0.001 mg/m^3 to 100 mg/m^3 and a resolution of one per cent of the measuring range. (Martikainen, 2006b)

All tests were carried out starting from about 30 minutes after installation of the mesh material. This delay gave time for the airflow to stabilize and to find new paths of less resistance if need be. This also demonstrated the water collecting ability of the tested mesh fabric and whether or not the water drained down the net. Each test took about 10 minutes to perform in one location.

Materials

Of the four tested materials, one was also tested at the Pyhäsalmi Mine. The material with the best fog removal characteristics based on the tests at the Pyhäsalmi, grey mosquito net was chosen at first. Unfortunately, this material was not available at the scheduled testing time. This resulted in choosing another material to be tested to get comparison values. The filter fabric G3, which had a problematic water bearing behaviour, but which was good at humidity removal was put to another test.

The materials tested at the Orivesi Mine were the filter fabric G3, fibrous filter fabric used typically for underground water filtering named Bidim S02, a white plastic greenhouse net, and an aluminium mosquito net covered with a thin paint layer. The materials are presented in Figures 2-5.

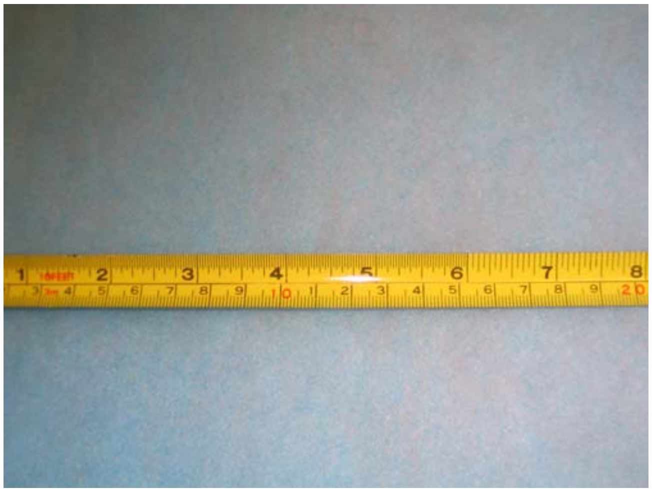

Figure 2. Filter fabric G3.

Figure 3. Fibrous filter fabric Bidim S02.

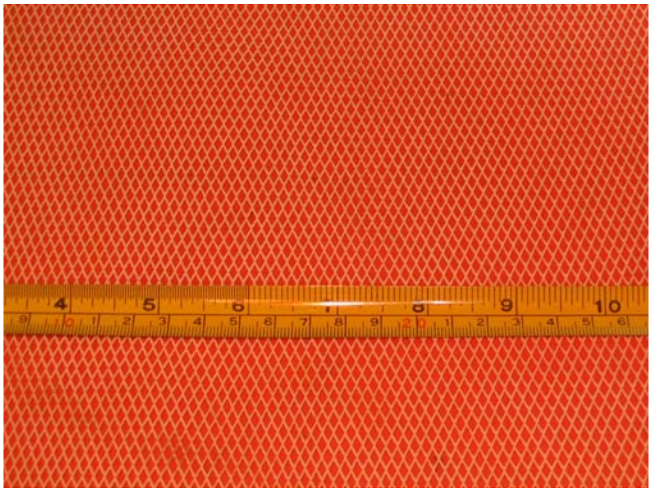

Figure 4. White plastic greenhouse net.

Figure 5. Aluminium mosquito net.

Thickness of the filter fabric G3 is about 1 cm. Fibrous filter fabric Bidim S02 is designed for distinction and protection of soil as well as for water filtering purposes in geoconstruction. This material is made of bound fibres with a thickness of 1.5 mm. The plastic greenhouse net has vertical perpendicular square holes of about 4 mm diameter. Aluminium net has a hole diameter of 1.2 mm.

Results

The measurements were performed over a span of two days. Two materials, both filter fabrics, were tested on the first day, and the remaining two meshes during the second day. Measurement results of the first testing day are presented in Table 1, and results of the second day are shown in Table 2.

The fog was uniform and its thickness was moderate during all tests. The largest fog droplets were visible with the naked eye.

Filter fabric G3 behaved pretty much the same way as at Pyhäsalmi. It collected a lot of moisture, but it soon became heavy and imbued with water. Air velocity decreased, especially downstream of the mesh. Air temperature and dew point temperature were quite stable. As there were few particles in the air, almost no change was observed in particle concentration.

Fibrous filter fabric Bidim S02 lowered relative humidity noticeably, as much as 3 %. Air temperature and dew point temperature remained quite stable across the mesh. Air velocity decreased somewhat, but the downstream values were higher than with the filter fabric G3. Bidim S02 gathered a lot of moisture and water was observed to trickle down the material.

Table 1. Measurement results of the first day

Filter fabric G3					
	Particle concentration	Air velocity	Temperature	Relative humidity	Dew point
Units	*mg/m³*	*m/s*	*˚C*	*%*	*˚C*
Upstr.	0.012	1.2	10.3	89.1	9.0
Downstr.	0.01	1.1	10.5	87.5	9.2
Fibrous filter fabric Bidim S02					
	Particle concentration	Air velocity	Temperature	Relative humidity	Dew point
Units	*mg/m³*	*m/s*	*˚C*	*%*	*˚C*
Upstr.	0.193	1.1	10.2	90.4	9.1
Downstr.	0.004	1.3	10.6	87.4	9.3
Baseline					
	Particle concentration	Air velocity	Temperature	Relative humidity	Dew point
Units	*mg/m³*	*m/s*	*˚C*	*%*	*˚C*
Upstr.	0.011	1.4	10.4	89.7	8.8
Downstr.	0.01	1.8	10.3	89.4	8.8

Table 2. Measurement results of the second day

White plastic greenhouse net					
	Particle concentration	Air velocity	Temperature	Relative humidity	Dew point
Units	*mg/m³*	*m/s*	*˚C*	*%*	*˚C*
Upstr.	0.549	1.2	10.2	94.3	9.8
Downstr.	0.275	1.4	10.2	93.1	9.7
Paint-coated aluminium net					
	Particle concentration	Air velocity	Temperature	Relative humidity	Dew point
Units	*mg/m³*	*m/s*	*˚C*	*%*	*˚C*
Upstr.	0.222	1.1	10.3	92.4	9.1
Downstr.	0.011	1.1	10.6	85.7	8.4
Baseline					
	Particle concentration	Air velocity	Temperature	Relative humidity	Dew point
Units	*mg/m³*	*m/s*	*˚C*	*%*	*˚C*
Upstr.	0.753	1.3	10.4	91.2	9.1
Downstr.	0.778	1.2	10.1	92.0	9.4

The white plastic greenhouse net decreased the particle concentration quite well, but otherwise it was considered to be the worst material tested yet for fog removal purposes. It actually collected droplets on both sides of the net and inside mesh holes as well. This caused the air flowing through the mesh to actually gain moisture and caused a thickening of the fog all around the net. None of the water drained off of this net. The measured relative humidity values were higher than without a mesh and also the dew point temperature rose.

Installing the aluminium mosquito net resulted in the best fog removal values. The decrease in relative humidity was 6.7 % and also a change in dew point temperature was noticeable. Water drainage was good, as it flowed down the net in streams. The aluminium mesh also collected a lot of particles. With this material a change in fog thickness was observed downstream where the fog became lighter.

Discussion and further studies

The temperature difference between dew point temperature and air temperature was about 1 ˚C without a mesh. This was also the case with both filter fabric materials. It was observed that with white greenhouse net this difference decreased to less than 0.5 ˚C. In the case of the aluminium net, the difference increased to more than 2 ˚C.

It was suggested in (Martikainen, 2005) that about 3 ˚C difference of dew point temperature and air temperature is enough to prohibit fog formation. This temperature – dew point spread gives an idea about the scale of the humidity decrease required in order to achieve fog removal. This information can be used in evaluating fabrics and also as a guideline in further fog removal surveys.

The prime result obtained with aluminium net was considered to be a consequence of the thermal conductivity of the material. As it is a metal, the thermal conductivity of aluminium is high. The high thermal conductivity of the aluminium mesh allows the fabric to experience quick, small temperature changes. With a turbulent airflow and a moderate air velocity lower temperature pulses affect the mesh. The cooler the surface of the mesh relative to the environment the more moisture it is able to collect.

A significant result was also received from testing the white plastic greenhouse net. It is good to know that an unsuitable material may result in an even worse fogging situation than originally observed. This shows that not just theoretical knowledge is enough, but on-site testing, and careful planning are essential in developing fog removal methods.

In comparison with Pyhäsalmi results, it is noteworthy that both the best and the worst results were achieved at Orivesi. White plastic greenhouse net was worse than any of the tested materials, and the opposite was true of the aluminium net. This shows that search for ideal materials is not in vain, as the characteristics of the materials are of extreme importance when considering the fog removal capacity.

Even if complete fog removal was not achieved with the tested materials, the tests showed the temperature-dew point spread required for fog removal was almost reached. The humidity decreasing effect of aluminium net was considerable and more profound than that of any of the previously tested materials.

Further studies to find materials with even better fog removal characteristics are being prepared. Also a question concerning multiple mesh systems should still be answered. The effectiveness of the method is still questionable, as no complete fog removal has been achieved with any of the tested materials. The research in order to validate the method continues.

Acknowledgements

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