INVESTIGATION AND MANAGEMENT OF PROTECTION SYSTEMS FOR UNDERGROUND TRANSPORT

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Abstract:

In this study a new method for tunnel ventilation was developed using high-speed roller doors mounted at tunnel entrances and exits at each of the metro stations. The method will improve ventilation efficiency and reduce high concentrations of harmful fine particulate matter (FPM) in two ranges, with particle sizes of less than 10 microns and less than 2.5 microns polluting the air in tunnels and subway stations as a consequence the movement of trains and people. Additionally, it will contribute to increasing safety and reducing energy costs by maintaining a comfortable and secure environment for passengers and staff in stations and tunnels. The used method is simulation and modeling using computing techniques and software to determine airflows in tunnels and metro stations.

Subject of the dissertation

Research and optimization of various innovative approaches for management of underground public transport systems to improve air quality and passenger safety.

1. Introduction

High concentrations of FDP cause many diseases and respiratory problems worldwide. The metro is used by millions of people around the world daily /only in Sofia over 450,000 passengers use the metro per day with a tendency to increase their number with increasing lines/. Ensuring the health and safety of passengers and staff is essential.

Also, the danger of terrorist attacks has increased in recent years. Some of the most vulnerable places are in urban transport infrastructure, especially metro stations and tunnels. Here there is a coincidence of crowding of large numbers of passengers, relatively little place for reaction and exit, as well as large and expensive engineering facilities.

Objective of the survey - Innovative approaches to the management of protection systems in underground public transport in order to improve air quality and passenger safety.

2. Software using discrete element method

It is chosen software, working on discrete element method for investigating the behavior of the iron ore in AG mill. The software can provide results like mass of particles, volume, velocity, torque compressive force, potential energy, etc.

The selected software is generally segmented on three modules. The first module is the creator section, where parameters such as used materials, equipment geometry, physics, etc. are selected. Another step in this section is the particles properties, needed for setting simulations. Properties of the particles includes: density, Poisson's ratio, coefficient of static friction, coefficient of rolling friction, coefficient of restitution, and interactions between materials of particles and geometry. The next parameter in creator tab is the equipment properties, which is used for setting the material and properties of the used in the simulation equipment. After setting all the particles parameters and equipment parameters, next needed parameters to set are the geometries, used for the simulation

The software gives opportunity to import geometry from other Computer-Aided Design (CAD) software, which eliminates the possibility for wrong, or not accurate CAD models and particle behavior. In the CAD model, also can be chosen different properties of the objects and movements such as linear rotations, linear translations, acceleration, velocity, etc. The chosen software also provides different models of calculations of the simulations. Some of the models are Hertz-Mindlin (no slip), Hertz-Mindlin (no slip) with RVD Rolling friction, Hertz-

Mindlin (no slip) with JKR Cohesion, etc. An attempt for simulation the behavior of iron ore in AG mill is selected the Hertz-Mindlin (no slip) model. The Hertz-Mindlin (no slip) model is based of Hertzian contact theory (1882) and the Mindlin model is based on the tangential force.

3. Metro and general requirements

The metro (abbreviated to the Greek metropolis: city-mother, also known as the underground railway) is a fast public transport.
The subway is designed with stations at important transport hubs, office buildings, shopping centers, landmarks, neighborhoods and other sites..

Metro lines and their individual sections may be underground (tunnels), terrestrial and overground (bridges and estacades). The total length of the lines in different cities may range from 2-3 kilometers. to over 1300 km. (subway in New York).

The benefits include:

- Fast and efficient (high capacity) - Typical capacity is 1200 passengers per train or 36 000 passengers / hour. They can also reach up to 80,000 passengers per hour.
- Reliable transport / Accurate timetable /
- Comfortable transport
- Others

Due to the extensive use of underground transport, the ventilation system is essential for the comfort, health and safety of passengers and staff. It must be designed to provide a comfortable environment for passengers and handling personnel at their normal operation (temperature and air quality). The system should be able to deliver fresh air during the "peak hour" as well as control the smoke movement and direction and ensure safe evacuation during an accident.

More important requirements:

 Removal of generated heat

- Subway trains can be regarded as moving sources of heat. Heat generation is mainly generated by the braking system, train air conditioning systems, etc., as well as by passengers.
- The most effective way to remove heat is immediately after it is generated to prevent it from spreading into the environment of the station and tunnels.

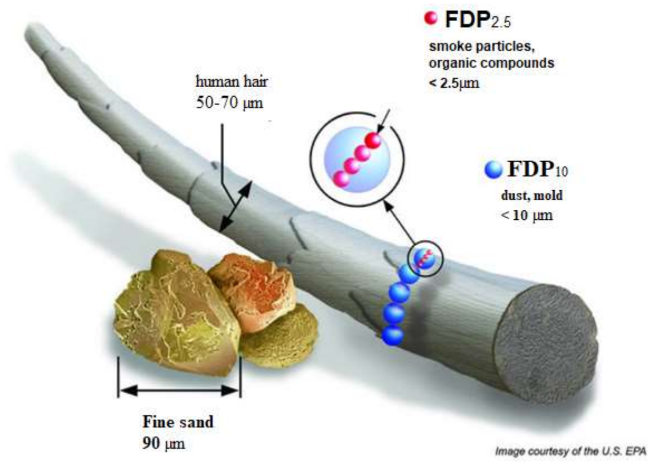

Fig. 1. Particle size attributed to human hair

 Ensure good air quality

- A number of air quality studies have been conducted in the subway and, as a result, because of train movements, concentrations of fine dust particles (FDP2.5 and FDP10), and in particles concentrations of iron, magnesium and chromium exceeded the values of air overground /over 100 times on New York subway.

- Impact on human health.

The dust comes into the body primarily through the respiratory system, where larger particles are retained in the upper respiratory tract, and the finer particles (below 10 microns - FDP10) reach the lower respiratory tract, causing damage to the tissues in the lung (Fig. 1). Children, adults and people with chronic lung disease, influenza or asthma are particularly sensitive to high FDP10 values.

The harmful effect of dust pollution is more pronounced with the simultaneous presence of sulfur dioxide in the atmospheric air. Their synergistic effect on respiratory organs and open mucous membranes was established. It is irritating and depends on the duration of exposure. The short-term exposure to 500 mg/m3 of dust and sulfur dioxide increases the overall mortality rate in the population, and at half-lower concentrations there is an increase in morbidity and impairment of pulmonary function. Prolonged exposure to sulfur dioxide and dust is manifested by an increase in non-specific pulmonary diseases, mainly respiratory infections of the upper respiratory tract and bronchitis at significantly lower concentrations (30-150 mg/m3), which is particularly pronounced in children. The most vulnerable to the combined effects of dust and sulfur dioxide are chronic patients with bronchial asthma and cardiovascular disease. The harmful effects of exposure to high concentrations of metal dust particles have been documented in a number of toxicological and epidemiological studies. In samples taken from a Stockholm metro, there is an 8 times greater likelihood of DNA damage and four times higher probability to cause oxidative stress (diabetes, cancer, Alzheimer's disease, arthritis etc) in cultivated lung cells. Samples taken from three London metro stations have a higher inflammatory potential and are more likely to cause DNA damage in cultivated human epithelial cells than in overground FDP.

Particle characterization in the subway - The particle distribution and type was made in a study [9] conducted in South Korea with samples of dust particles taken from different locations in several stations (Fig. 2).

In case of a fire in a tunnel or a metro station, the greatest danger is not the flames, but the inhalation of the poisonous gases generated by the burning toxic products (Over 70% of the victims are in case of poisoning). Most toxic and most commonly released in case of fire are oxides of hydrocarbon CO /binds to blood hemoglobin 200-300 times faster than oxygen - there is oxygen starvation of the organis / and CO2 - cause of 50-80% of the dead. CO2 replaces oxygen in the blood, speeds up breathing, so larger amounts of other gases are absorbed in more dangerous concentrations, at 10% - man loses consciousness. In the event of a fire or a terrorist attack, harmful gases must be removed as quickly as possible from the metro area while providing fresh air for passengers, personnel and firefighters.

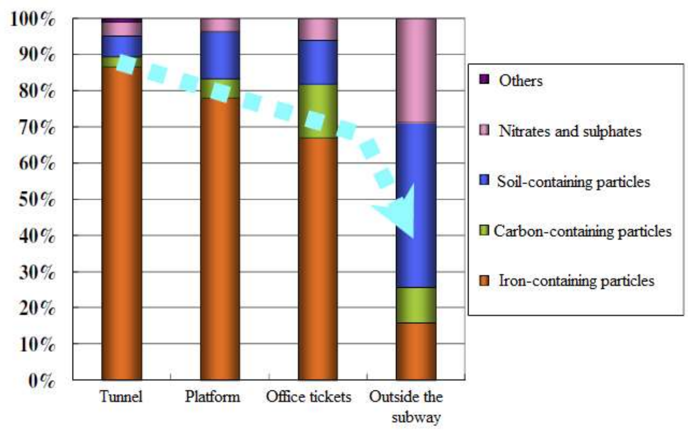

Fig. 2. Particle distribution by classes

Terrorist Attack - the main ways of attacking (sarin, anthrax) are by putting them on the station, on the train or in the tunnel - possibly through the ventilation shaft. The propagation occurs when trains run through the stations and tunnels. Installing detectors and CCTV and analytical software could reduce response time and take immediate action.

4. Technological level and developments at that time

There are several approaches to improving the subway environment:

• Installation of automatic sliding doors on the stations, fig. 3:

Advantages: Reduces noise, dust, wind, prevents accidental drops from the platform, improves climate control of stations, reduces jamming on rails and tunnels /against fire/.

Fig. 3. Sliding doors on a station

Disadvantages - a high cost of fitting, maintaining and adjusting the doors to those of the trains, reduces the effect of natural ventilation, which increases the cost of ventilating the subways. There are incidents incl. deaths in which a passenger falls between the closed door of the train and the sliding door of the platform.

• Air curtain. In the recent years, studies, tests and simulations using air curtains have been conducted, [10]. As a result, dust particles pollution is reduced and tunnel ventilation is improved. A disadvantage can be the power consumption and the generated noise that cannot be distributed effectively in the environment. Research has found that an air curtain effect will have when the airflow rate is at least 25 m/s, and studies with 60 m/s and 80 m/s have been made, /fig.4/.

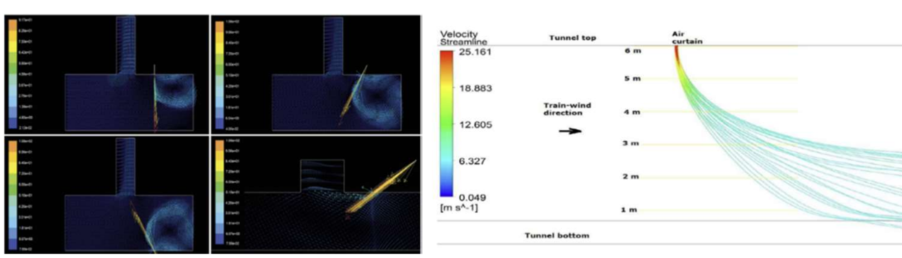

Fig. 4. Simulation of air curtain

• Use of a vacuum train to clean tunnels from dust and debris - Fig. 5,

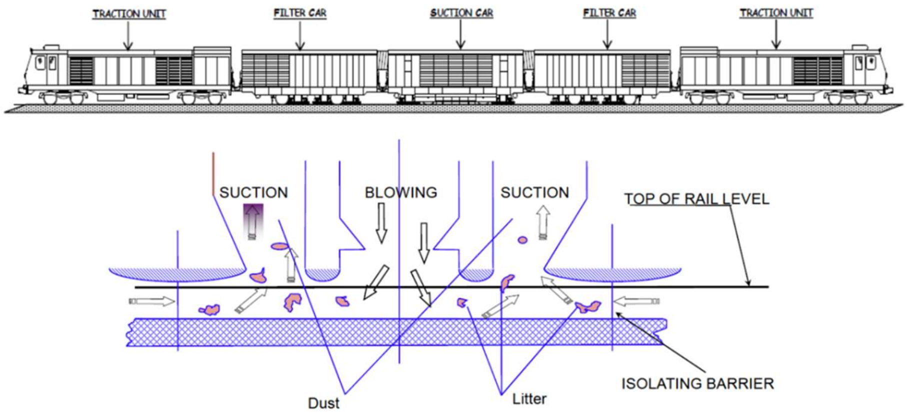

Fig. 5. Vacuum train to clean tunnels from dust and debris

5. Ventilation in the subway and tunnels

Natural ventilation in the subway is mainly the result of the movement of trains through the tunnels. Airflows are similar to those caused by the piston movement in a cylinder and for this reason it is called ventilation of a "piston effect".

"The effect of the piston" is a phenomenon and is the cause of the air movement from the tunnels to the metro stations as well as the change in pressure. From a ventilation point of view, air movement is functional and helps to exchange air, tunnel cooling, etc., but when the "plunger effect" is more, it is the cause of high air velocities on the platform and corridors. To reduce the high air velocity, shafts are designed to deviate the air from the tunnels to the atmosphere and reduce wind gusts in the stations. Gusts of wind enter the stations as a stream that expands in the cross section of the station and reaches about 15-45 m/s inside it. Normally, the wind speed should not exceed 5 m/s when entering the station.

Stairs, escalators and entrance corridors also act as ventilation shafts, and the "piston effect" can cause excessive air velocities in these areas.

The air flows in the subway are generated by two main sources: the "piston effect" of train movements through tunnels and, in some cases, mechanical ventilators. A natural source of air is also the staircase and other openings. Factors that affect airflow are geometric parameters such as: location, shape, length, cross-section, perimeter, roughness of walls in tunnels, stations and ventilation shafts, as well as dynamic parameters: train speed, acceleration, stroke, as well as the performance of the fans. The air temperature, its speed and pressure depend on the design of the tunnel ventilation system. "The effect of the piston" is the cause of the air flow through tunnels from the tunnels to the outside atmosphere, and in the opposite direction - a stream of fresh air when the train passes through the shafts.

The hot and warm air generated by the train braking system and the air conditioning system is mixed with that from the tunnel behind the train, which is subsequently transferred to the station due to the remaining momentum or pulled out as a result of the train's departure.

The "piston effect" generated by train movements is in most cases sufficient to maintain a good level of ventilation.

6. Air filtration

Air filters are generally classified based on their collection efficiency, pressure drop (airflow resistance) and particle retention capacity. Two test methods are currently in use: European Standard EN 779 and US Standards ASHRAE 52.1 and 52.2 for Classification of Ventilation Air Filters. The classification of these filters is based on the efficiency gained from conducting experiments.

The American standard ASHRAE has confirmed the so-called MERV - minimum efficiency reporting value, values by which manufacturers evaluate the performance of their filters. To measure this efficiency, 12 sizes are entered. The smallest particle size is 300 nanometers.

Rough and fine dust filters are most commonly used for air purification. Based on their performance, the EN779 classifies the various fine-grained F5-F9 filters, where F5 is less efficient and F9 is the most efficient of all. Class filters G1-G4 are coarse filters.

The MERV / HEPA / ULPA filters are used for air purification in laboratories, industrial premises, clean rooms, hospitals, electrical appliances, and more. Fig. 6.

Depending on the selected filter, it is possible to filter: bacteria, 90-99% fine particle size 2.5-10 microns, mold spores, etc.

7. Modeling and simulations

To verify the effect of the installation of safety doors at both ends of the metro station (at the tunnel entrance and exit), 4 models are created and simulations were made with the software product Solidworks Flow, as follows:

- Simulation with general conditions (without doors and filter bodies) - model 1
- Simulation with mounted doors and filters MERV15 - model 2

- Simulation performed without mounted doors and filters - with ventilation included – model 3
- Simulation performed with doors and filters fitted and with ventilation included - model 4

A comparative analysis of the simulation results with the four models was made - fig. 6

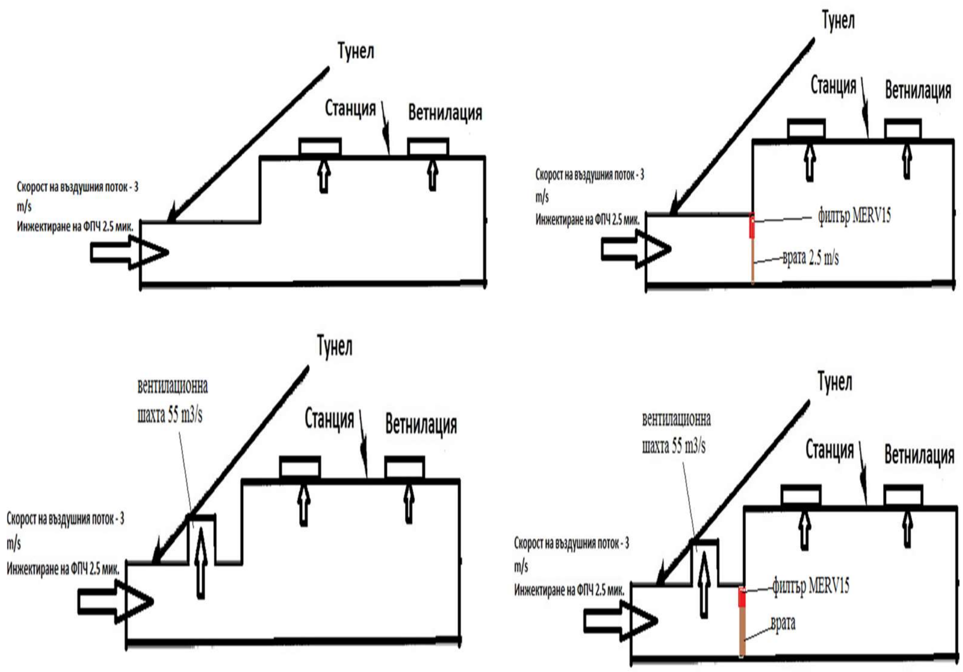

Fig. 6 Comparative analysis of 4 models

Conclusion: The results of the studies show that particle filtration by the aforementioned method will lead to self-cleaning of the PMF tunnels.

The reduction of electricity for ventilation, cleaning and other related activities will also be significant, due to the use of energy that has not yet been used. The important aspects of the proposed design expand their capabilities in the field of fire safety, protection against terrorist attacks, reducing response times, increasing awareness of the emergency situation, and responding appropriately and making important decisions on which human life depends.

Protecting the environment from pollutants (FPM) is also a very important task that has a solution with the proposed design. Daily breathing of high concentrations of fine particulate matter contributes to the development of diseases and the reduction of human life, not least the medical expenses.

Using the EDEM SOFTWARE software package, simulations were made to movement a train in a tunnel (fig. 7) and to produce fine particles when a brake was triggered (fig. 8).

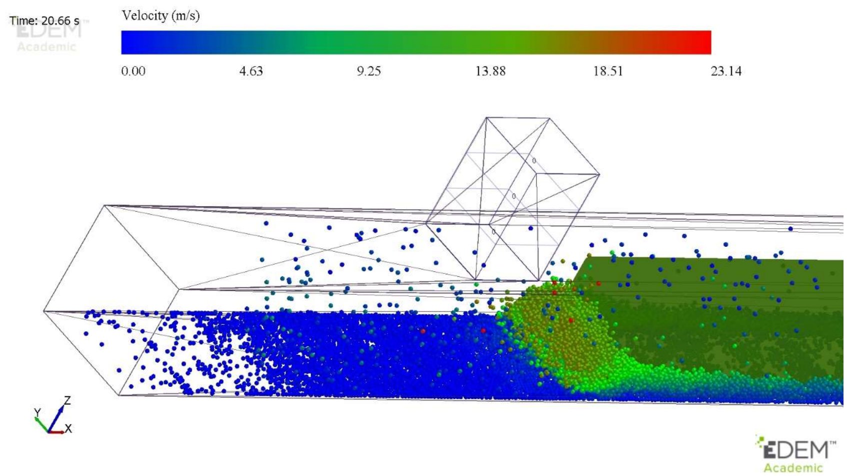

Fig. 7 Simulation of movement a train in a tunnel

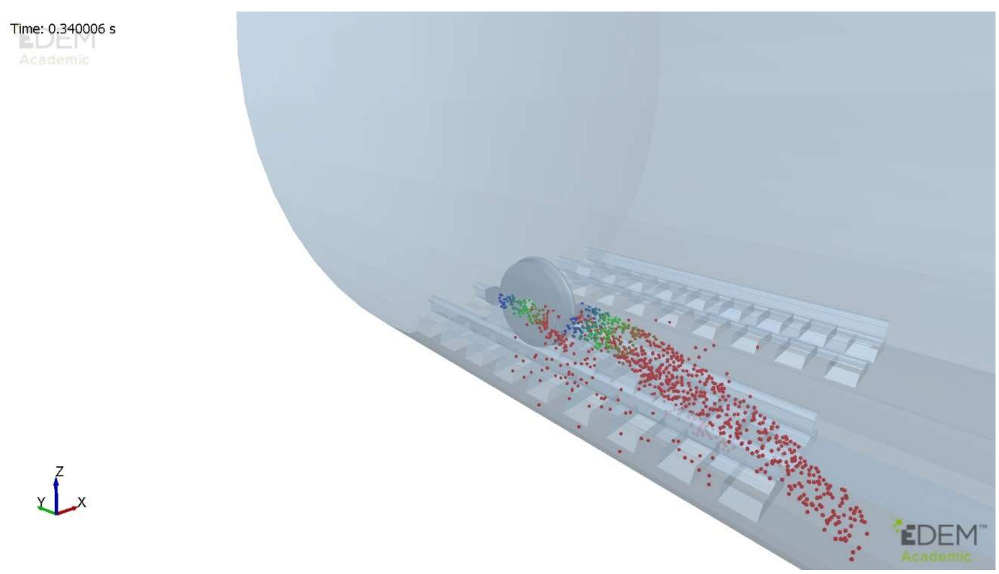

Fig.8 Simulation of a brake and fine particles

8. Conclusion

Air cleanliness and subway safety are of great importance due to the fact that this mode of transport is used by millions of people. The presented in the paper pollutants and methods for their cleaning improve the environment in underground urban transport and help to increase security.

Scientifically-applied contributions:

In accordance with the objective, the studies and the obtained results, the following scientifically-applied contributions have been achieved:

- After a detailed review and analysis, a systematization of the types of factors influencing the safety and security of the underground rail transport is made,
- Concentration of fine particle matter in the subway has been investigated and the main types and sources of pollution are identified,
- Existing solutions for reducing particle matter concentration and improving safety in underground rail transport have been investigated and are being analyzed,
- A scheme is proposed for the optimization of ventilation in the subway and tunnels,
- Innovative approaches are proposed with the use of upgraded underground rail transport protection systems,
- Experimental results and simulation modeling with new protection systems are presented, the different models are analyzed.