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Technology of Recovering Mechanical Impurities from Ventilation and Degasification Emissions from Coal Mines.

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ABSTRACT

The article concerns the process of the effective recovery of mechanical impurities from ventilation and degasification emissions from coal mines. The process of ANSYSCFX-aided simulation of mechanical impurities recovery has been shown. The design solutions for the dynamic filter used to effectively remove mechanical impurities from ventilation and degasification emissions, which have passed through the gradient separator, have been set forth. The efficiency of mechanical impurities recovery using a dynamic filter is extremely high and can reach 99.8%.
Keywords: Dust and methane emissions from coal mines, ventilation, degasification, methane-dust-air mixture, dynamic filter, mechanical impurities recovery, efficiency of mechanical impurities removal.

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Mechanical impurities, i.e. air dust from coal mines and opencasts, contain coal and non-coal particles. The content of mineral substances in mechanical impurities varies from 15 to 40%. The concentration of dust, in such a case, can reach hundreds of milligrams in 1 m^3. In case of dry drilling, air dustiness can reach 1000 mg/m^3. The content of dust 0.1-0.2 µm is most hazardous. The dispensability of airborne dust can be as follows: 40-80% of dust particles are in size of to 1.3 µm; 15-35% – to 2.6 µm; 5-20% – to 4 µm; 3-10% – over 4 µm [1].

The basic operations related to dust emission include coal mining with a coal-mining machine, undercutting coal bed with an undercutting machine, manual coal breaking and coal breaking with pneumatic coal hammers, coal loading onto the transporter, coal breaking at steep coal beds with pneumatic coal hammers, transporter-to-car coal loading, "tunnelling machine" operation, drilling and blasting, machine loading of rock, car conveying to the shaft, skip discharge [1].

Not all of the above operations are equal in terms of dust intensity. The research has shown that 95% of the overall dust is formed in coal faces. Of the total amount of coal formed, operation of mechanisms accounts for 60%, blasting operations in the coal face account for about 20%, coal freaking accounts for 10% and other operations – 10%.

Mechanical impurities formed in coal mines are lifted to the mine surface with ventilation and degasification emissions and, getting into atmosphere, create ecologically tense situation, and, when penetrating into machines and mechanisms, speed-up their abrasive wear and reduce their service life. Therefore, the effective cleaning of ventilation and degasification emissions constitutes a priority task.

In this respect, when developing processes for recovering highly concentrated methane from ventilation and degasification emissions, CJSC "COMPOMASH-TEK" encountered the necessity of mechanical impurities removal.

In order to ensure efficient precipitation of fly-ash, heavy metals and mechanical impurities, a dynamic filter for the gradient separator has been designed. Through the nozzle, installed in the center of the separation channel, and via exhaust fans, dust and gas mixture is directed to the precipitation hopper of the filter. The dynamic filter can be operated under negative stress only [2].

When designing a dynamic filter, the physical processes applied, to any extent, in other gas cleaning systems and industries have been converged. They are: cyclones and anticyclones, vortex and inertial dust collectors, aircraft engineering aerodynamics. As a result, a dynamic filter of fundamentally new design, unrivalled both in Russia and abroad, has been created. This technology allows to clean ventilation and degasification emissions from any suspended particles, including coal dust and fine particles of rock by applying the gas-dynamic method only, with no filtering medium used. The degree of purification accounts for 99.5% (cyclones and inertial dust collectors – to 80%) with minimum power consumption (exhaust fans draught is sufficient for equipment operation) [3].

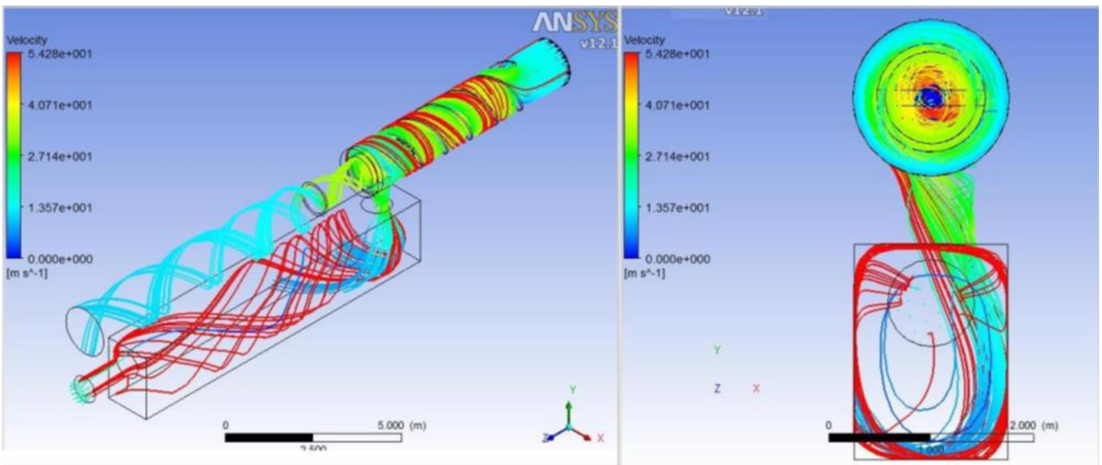


Figure 1. Scheme of the dust intake simulation (ANSYS_12).

The simulation of the process of recovering mechanical impurities was carried out using ANSYSCFX software package. Figure 1 shows some simulation results:

When the two-phase methane-air stream is moving (Figure 2) along the volume of the rotary chamber, it contacts with the precipitation lattice in that volume in which the methane containing mechanical impurities is relatively immobile. The particles of mechanical impurities from the high speed stream move into this volume and precipitate into the dedicated hopper.

But not all the particles of mechanical impurities are precipitated. A part thereof moves to the dynamic filter outlet, and here, under the influence of the incoming methane-air jet, they are redirected to the rotary chamber of the dynamic filter. This turns to be an aerodynamic trap – the particles have a possibility to enter the rotary chamber of the dynamic filter, but cannot exit it, and eventually precipitate in the hopper completely.

The studies showed that, in terms of the efficiency of ventilation and degasification emissions from dispersed particles of mechanical impurities, the dynamic filter is unrivaled throughout the world and outperforms bag filters, electrostatic precipitators and wet scrubbers. Besides, the dynamic filter operation does not require fabric filters and water washing. Figure 2 shows the tried and true design solutions for the dynamic filter.

A dynamic filter consists of: 1 – an inlet connection for methane-dust-air mixture; 2 – air supply channel for the methane-dust-air mixture; 3 – spin nozzle; 4 – rotary chamber; 5 – outlet channel for pure methane with residual air and residual mechanical impurities; 6 – dedicated hopper for mechanical impurities precipitation; 7 – clearance adjustment rod of outlet channel for pure methane with residual air and residual mechanical impurities.

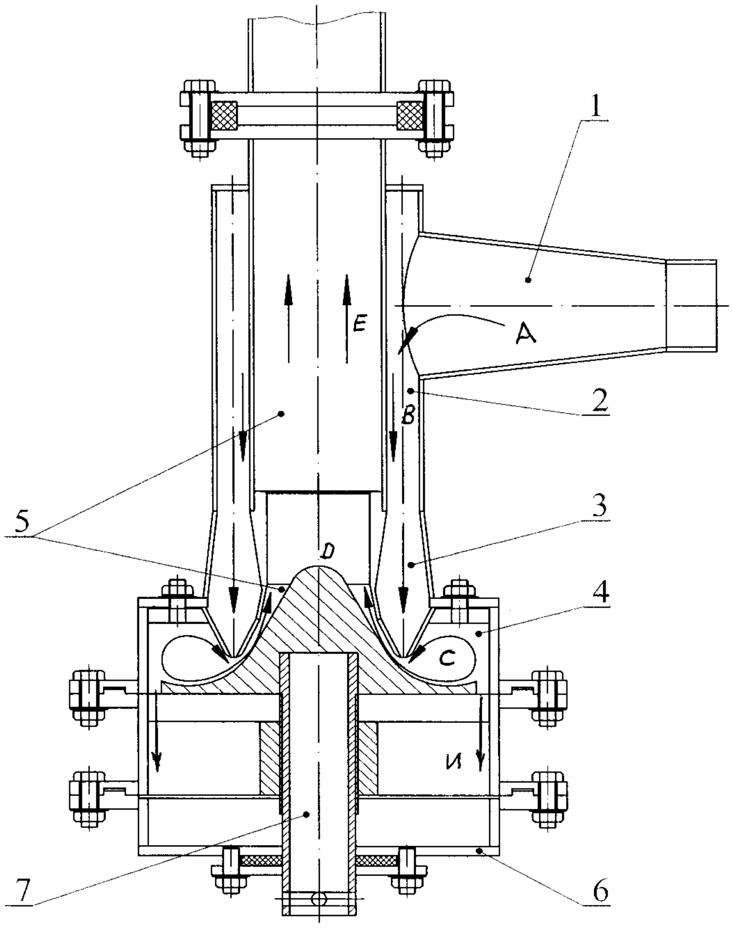


Figure 2. Design solutions for a dynamic filter.

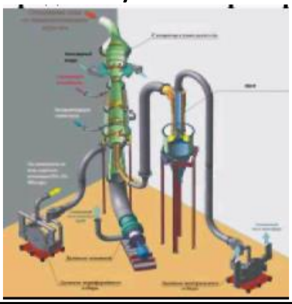
1 – inlet connection for methane-dust-air mixture (Stream A); 2 – air supply channel for the methane-dust-air mixture (Stream B); 3 – spin nozzle; 4 – rotary chamber (Stream C); 5 – outlet channel for pure methane with residual air and residual mechanical impurities (Stream E); 6 – dedicated hopper for mechanical impurities precipitation (Stream I); 7 – clearance adjustment rod of outlet channel for pure methane with residual air and residual mechanical impurities.

A methane-air mixture through the inlet connection (arrow A) enters the dynamic filter, then (arrow B) moves along the air supply channel and exits the spin nozzle (arrow C). At this section, a methane-air mixture is in the negative stress condition. Then the gas mixture jets turn back (arrow C), pass through the incoming jets, i.e. essentially pass through the filter formed from the moving layers of air, which is in the negative stress condition. When the gas stream is moving along the volume of the rotary chamber, it contacts with the precipitation lattice in that volume in which the gas is relatively immobile. The particles of the high speed stream move into this volume and precipitate into the hopper. But not all the particles are precipitated. A part thereof moves to the dynamic filter outlet, and here, under the influence of the incoming jet, they are redirected to the rotary chamber of a dynamic filter. This is an aerodynamic trap – the particles of the mechanical impurities mixture have a possibility to enter the rotary chamber of the apparatus, but cannot exit it, and eventually precipitate in the hopper completely. Therefore, the particles will be able to enter a channel, but will not be able to exit it.

The comparative evaluation of the options of the efficient mechanical impurities recovery from the methane-dust-air mixture from coal mines in the volume of 200 thousand nm^3/h has been summarized in the Table below.

Table. Results of comparative analysis of the efficiency of mechanical impurities recovery from methane-dust-air mixture in the volume of 200 thousand nm^3/h.

Processes of mechanical impurities recovery using:	Capital expenditures, including installation*	Current maintenance expenses	Operating costs	Deficiencies
Multicyclone 	**48 mln. rubles (almost not used in isolation due to low efficiency)**	Full replacement of cyclones at abrasive wear (once in several years)	Electric power supply to draught systems – 570 kW/h	Low efficiency – 85-90%. Abrasive wear – 90%. Minimum coarseness of collected particles – > 10 µm.
Scrubbers 	60 mln. rubles (limited use due to permanent consumption of process medium (water), necessity for screening, and corrosion)	Steel structures replacement in case of corrosion, from 5 mln. rubles	Electric power supply to draught systems – **570 kW/h;** - Pumping and supply of process medium (water, etc.) – depending on the supply method – to 50% and more of the operating costs; - Automation package – 5 kW/h	The wet method of cleaning requires the application of supplementary equipment for water reclamation and aggressive gas impact elimination, as well as rustproofing. Low efficiency – 85-95%. Minimum coarseness of collected particles – > 2 µm.
Bag filter	**80 mln. rubles** (almost never used upon the availability of	Replacement of filtering medium: from once a year, depending on the characteristics of dust particles	Electric power supply to draught systems – 570-1000 kW/h (at	High hydraulic resistance – fast wear of the bag filter material – requires shaking for regeneration.

Processes of mechanical impurities recovery using:	Capital expenditures, including installation*	Current maintenance expenses	Operating costs	Deficiencies
	sulfur dioxide)	– from 3 mln. rubles	temperature above 200 °C and upon the availability of sulfur dioxides – an increase in productivity of up to two times and more for gas dilution); - Automation package – to 5 kW/h	Temperature restrictions for passing gases. Ultimate service temperature – to 400 °C. Efficiency – 98-99%. Minimum coarseness of collected particles – >2 µm.
Electrostatic precipitators 	**200 mln. rubles** (most widely-used gas-purifying equipment in the RF Fuel and Energy Sector)	Replacement of electrodes: once in several years; expenses – from 10 mln. rubles	Electric power supply to draught systems – to **900 kW/h** due to the required gas flow low speeds; - creation of electromagnetic fields – 300 kW/h; - Automation package – to 10 kW/h	High cost of equipment and high operating costs (electric power). Temperature restrictions for passing gases. Ultimate service temperature – to 200 °C. Efficiency – 99%. Minimum coarseness of collected particles – > 5 µm.
Vortex swirling intensity with the use of a gradient separator and a dynamic filter 	**45 mln. rubles**	Replacement of the gradient separator internal assemblies subject to erosive wear – once in several years. Expenses – from 500 thousand rubles.	Electric power supply to draught systems – **500-570 kW/h**	Not found. Efficiency – 99.8%. Minimum coarseness of collected particles – < 1 µm.

Based on the above comparative evaluation of the efficiency of recovering mechanical impurities from methane-dust-air mixtures emitted from coal mines in the volume of 200 thousand nm^3/h, dynamic filter is deemed to be the most advanced.

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