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Dust prevention in bulk material transportation and handling

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Abstract. The environmental problem of territory and atmosphere pollution caused by transportation and handling of dust-generating bulk cargo materials is quite common for the whole world. The reducing of weight of fine class coal caused by air blowing reaches the level of 0.5–0.6 t per railcar over the 500 km transportation distance, which is equal to the loss of 1 % of the total weight. The studies showed that all over the country in the process of the railroad transportation, the industry loses 3–5 metric tonnes of coal annually. There are several common tactical measurers to prevent dust formation: treating the dust-producing materials at dispatch point with special liquid solutions; watering the stacks and open handling points of materials; frequent dust removing and working area cleaning. Recently there appeared several new radical measures for pollution prevention in export of ore and coal materials via sea port terminals, specifically: wind-dust protection screens, the container cargo handling system of delivery materials to the hold of the vessels. The article focuses on the discussion of these measures.

1. Introduction

The transportation of the bulk materials is one of the main article of the world trade, with ore and coal being the second and the third positions in the list of top transportation commodities by volumes. The nature of these materials makes the handling and transportation one of the most severe environmental problem, since the emanation of dust results in very intensive and dangerous pollution as Fig. 1 shows. This problem is well-recognized and studied worldwide [1 – 7]. Depending on the regional state of economy, the level of the national development, cultural traditions and geopolitical situations, the view on this problem varies greatly [8 – 16]. In the same time, the globalization of the world economy, the diminishing of the gaps between developed, developing and emerging countries, general perception of the environment vulnerability urge the world community to treat this problem more seriously and unanimously. The bibliographic survey shows ever increasing numbers of dedicated studies and proposals [17 – 24].

Several of these studies deal with the technological measurers proposed for the prevention of the dust emanation in bulk material transportation [17-19, 22]. Still, recently several new very promising and radical methods appeared, forming the focus point for this paper.

2. Wind-dust protection screens



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The dust prevention by the use of perforated wind-dust screens grows common today. These technologies exist in store yards and terminals in Canada, China, Japan and other countries. Depending on the direction of the wind, these screens could perform the wind-protection (when located upwind from the stack of material) or the dust protection function (when located downwind from the stack).

There are several common types and construction materials of the wind-dust screens: steel; synthetic polymer rigid; synthetic polymer sail-typed (made from «Weather Solve» tissue, Canada); electrostatic (made from DUST TEX NET tissue, Switzerland); polyether network («Dainichi Engineering», Japan).

Russian ports, R&D organizations and consulting agencies also conduct intensive studies concerning the application of these screens in big seaports. In particular, the Murmansk Sea Trade port is finalizing the project of construction of the wind-dust screens in. The variant of the screen layout is given in Fig. 1.

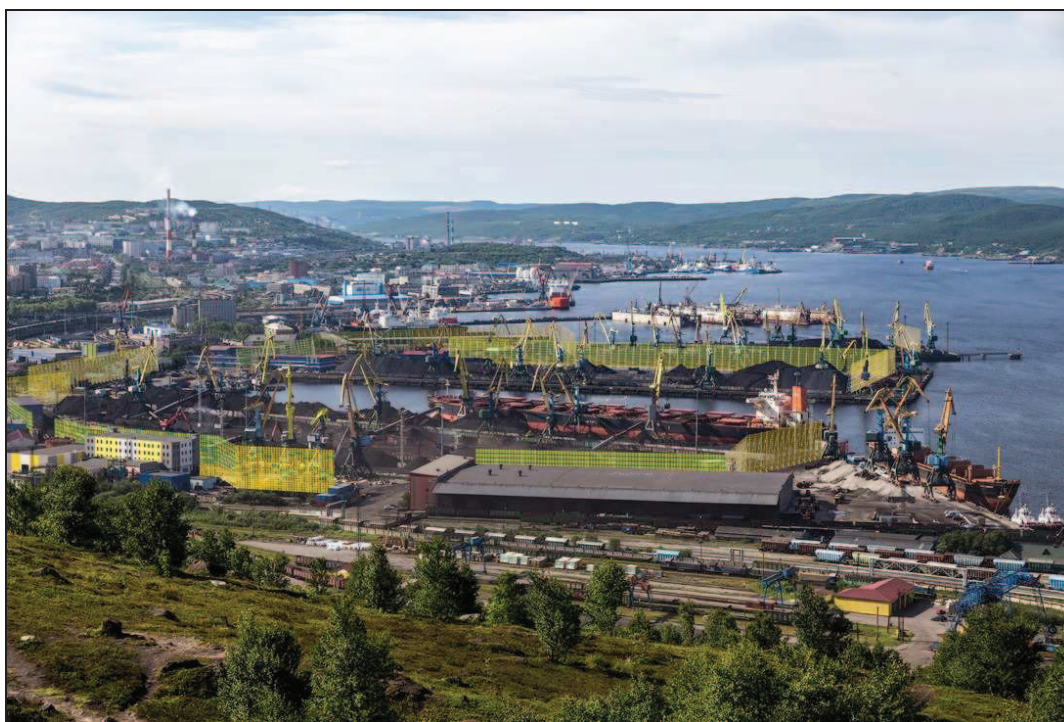


Figure 1. Project of the wind-dust screens in Murmansk port (colored yellow)

3. Main characteristics of the dust prevention by screening

The effect of the dust prevention screen is directly connected to the mechanisms of emanation, transfer, dissipation and sedimentation on the stack of bulk materials. The studies conducted in the aerodynamic laboratories provided data on the pressure and air flow directions upon hitting the solid and perforated planes. These data were used for comparative analytical studies for theoretical substantiation of the wind and dust prevention system's type selection. These studies revealed that the solid wall does not prove any efficient dust suppression.

The dust screen with perforated holes permits the wind flow to pass through the wall surface as Fig. 2 shows. In the zone A the probability that the wind velocity would exceed the critical value needed for dust creation drops dramatically. In zone B, the air flow passes through the perforated wall without bouncing or turbulence formation, thus reducing or eliminating the effect of dust emanation.

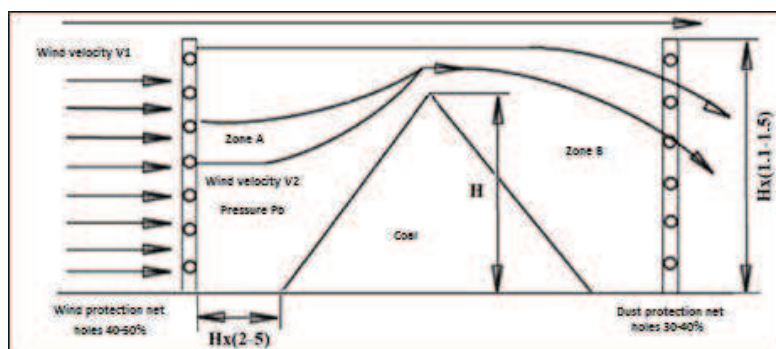


Figure 2. Wind routes blowing through the perforated screens

The results of the tests conducted in the aerodynamic tubes show that:

- the optimal height of the dust screen is 1.1–1.5 of the stack height;
- the height selection should take into account the total area of the open store so that stack would remain in the effective defense zone;
- at the distance 2–5 times bigger than the height, the dust suppression coefficient for the coal stack could be over 90 %;
- at the distance 16 times bigger than the height, this coefficient could be over 80 %;
- at the distance 25 times bigger than the height, still reasonable dust suppression exists;
- at the distance 50 times bigger than the height, the screen reduces the wind velocity by 20 %.

The construction of the dust screen around the stack should take into account not only the local prevailing wind directions, the sizes and the shape, but also the territorial features and engineering networks allocations, such as existence of buildings, mechanical equipment, undersurface pipelines, power cables, roads etc., so that the erection and exploitation of the screen walls do not interfere with the normal operation of the stack and its auxiliary equipment and do not cause the construction cost rise.

The experiments performed in the aerodynamic tubes revealed that the relative hole's size (the ratio of holes area to the total plane area) directly determines the wind velocity behind the wall, as well as the protection zone area. With this ratio of 30–50 % the screen provides the best impenetrability of the wind. This ratio is, by the way, the criterion distinguishing between wind screen (40–50 %) and dust screen (30–40 %). The joint utilization of the wind and dust screens provides good wind impenetrability.

The results of mathematical and physical simulations of the influence of relative holes size and the screen height on the dust suppression ability are shown in Tab. 1 and 2.

Table 1. The dust suppression coefficient as the function of the screen relative holes size

Wind velocity (m/sec)	Screen height (m)	Perforation ratio (%)	Mean dust suppression coefficient (%)
10	20	30	93
		20	94
20		30	81
		20	82

Table 2. The dust suppression coefficient as the function of the screen height

Wind velocity (m/sec)	Screen height (m)	Mean dust suppression coefficient (%)
10	18	90

	20	93
	23	95
	18	77
20	20	81
	23	84
40	20	75

When constricting the perforated walls not only static wind pressure should be taken into account in accordance with a standard static tension and shifts analyses, but the dynamic pressure on the perforated construction, frontal resistance and vibrations.

For the design and construction of the dust screens, the following data should be retrieved:

- materials of the engineering investigations (geology, hydrometeorology, geodesy, ecology);
- results of mathematical simulation for rationalizing the screen height and plane layout in accordance with local climate, relief, building development etc.;
- sizes and location of the stacks of materials, characteristics and positions of handling points.

The indicators of relative costs by different equipment manufacturers with different construction materials and the dust suppression coefficient over 80 % and screen height of 18 m are given in Tab. 3.

Table 3. Comparative study of manufacturers

Country	Company	Screen material	Support gauge (m)	Servicing	Cost ratio
China	GREEN TIANJIN	Steel plate	6	min	1
Japan	Dainichi Engineering	Polyester	12	medium	4.8
	Long Barrie	Steel plate	12	min	5.2
Canada	Weather Solve	Tissue	20	medium	2.1

In comparison to the dust screens it is necessary to take into account the cost of support constructions which could be around 55 % of the total project price. The typical life cycle of the screen is 20–25 years.

4. Container transportation and handling system for bulk materials

The globalization of the world economy and trade has turned the container transportation into a highly developed and sophisticated industry. In accordance with the information published by the companies Containerized Bulk Handling Group and Intersafe Marine AB, recently we witnessed a technological revolution in bulk materials handling. Now it is possible to transport, store and, which is most important, to load bulk cargo into the holds of bulk carriers directly from “the boxes”, i.e. standard containers. The main technological solution, which made it possible, turns out to be revolving cargo handling devices, specifically RAM Spreaders.

The new technologies of bulk material transport (including dust-generating cargo) appear, based on the use of special containers from point of material flow source to the point of ship load, when the containers are tipped and materials fall freely in the holds.

There are several variants of container utilization in the transportation/handling of bulk materials, starting from the total intermodal delivery over the whole logistic chain to the port operations only. In any way, there is a need for a relatedly new and complicated devise – the revolving spreader (Fig. 3).



Figure 3. Revolving spreaders made by RAM company

The revolving spreader automatically opens the upper lid and tipples the container, holding the lid. One of the principal condition for normal operations with this spreader is a close proximity of the gravity center of the container to the pivoting axle, preventing the appearance of excessive rotating moment, affecting the spreader's tipping mechanism. Accordingly, there is a range of container types available for different unit weight materials.

The containers could be used also as a component of the in-terminal cargo handling system only. An example gives the Smart-Bulk Terminal in Ust-Luga Sea Trade port, where the bulk cargo (mainly fertilizers) are transported and loaded with 20' containers used as handling tare. The same concept is realized on Terminal 2 of St. Petersburg Trade port (Fig. 4).



Figure 4. Ust-Luga Sea Trade port, bulk material handling in containers

The Smart-Bulk Terminal operates on the rented territory, where of all capital facilities only railcar dumping/container loading station is built. The discharging of containers into the ship's hold is performed by the harbor mobile cranes equipped with the revolving spreaders. For this purpose any available berth can be used meeting the ship's requirements.

Another direction of the transportation business diversification is in development of the cargo handling technologies enabling one to use free capacity of dedicated container terminals using their standardized handling equipment. The main relevant sub-tasks for the problem are:

- provision of the bulk container loading station at the storage yard;

- equipping the ship-to-shore container handlers with special rotating spreader for emptying the container into the holds of the ships.

The standard 20' open top dry container could be used for the purpose, including used one and even not fitting for the general transportation purpose. For the open railcar discharging at the operating container terminal railhead the existing rail-mounted gantry cranes can be used, equipped for this purpose with motorized grabs. Fig. 6 presents a technological cut view of the rail cargo front with preliminary cleaning of the coal with magnetic separators at the mobile crushing/sorting complex. For the dust suppression around the complex, the wind-dust prevention screens should be provided.

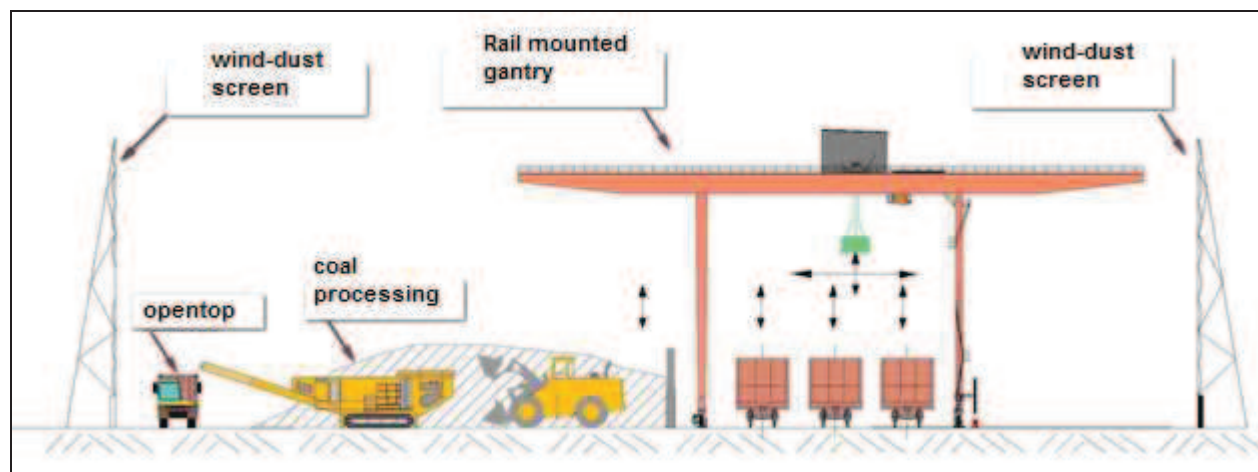


Figure 5. The technology of railcar discharging and coal processing

5. Conclusion

Dust-wind screens prove to be an effective engineering solution for the environmental problems caused by bulk material processing at handling points.

The containerization provides new technical solutions for the dust emanation problem along the whole supply chain of bulk material transportation. The use of standard containers for bulk material transportation/handling provides pre-conditions for the transport business geographical mobility. The container technology opens a new degree of operational flexibility inside ports and terminals.

The box-type handling of bulk material provides the missing liquidity of the technology: with the deterioration of bulk material flows, there is no need for demolishing any buildings and erections, with the equipment and tare highly demanded on the market.

The storage of the coal in tare provides new opportunities in comparison with open storage, e.g. keeping coal brands separately facilitates blending and order consolidation.

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