The Study of Slip at the Surface in Terms of Carbon Dust

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Abstract. In this paper, an experimental study of the dependence of the coefficient of friction in the “sole-floor” system under various conditions is carried out. During the test, a tile was used as a support surface. Part of the sole of a special Shoe was placed on a tile and, slowly lifting the tile, determined the angle at which the movement of the Shoe sample begins. The sole and surface of the tile were specially prepared: cleaned before testing or applied a layer of graphite, rubbing into the surface. The studies were performed under various conditions: a clean Shoe sample and a clean surface, a Shoe sample and a surface contaminated with graphite dust. A graphite electrode powder with a grain size of no more than 0.1 mm was used as graphite dust. Graphite was applied to the tile surface in the form of a loose layer, or with a small seal. Analysis of the results shows that the highest coefficient of friction occurs between a clean Shoe sample and a clean floor surface, which is difficult to achieve in real production conditions. This combination is the safest in production conditions. The lowest coefficient of friction is obtained when a Shoe sample contaminated with graphite slides when there is a loose layer of graphite on the floor surface. This leads to the conclusion that it is necessary to clean the floor surface and shoes from carbon dust to ensure a safer environment for production workers in the presence of carbon-containing dust in the air of the working area. The results obtained can be useful for developing recommendations on the organization of safe working conditions at enterprises associated with the processing of carbon-containing materials.

1. Introduction

In the conditions of modern production of graphite products, various types of dust are released, most of which is carbon dust. The study of the impact of carbon dust in the air of industrial premises on employees is an urgent problem of technosphere safety [1, 2]. Carbon dust in the air has a negative impact on the human body, contributes to the occurrence of emergency situations. In this regard, the main attention of researchers is focused on the issues of explosion hazard of coal dust [3-7], especially dangerous is the mixture of coal dust with methane [8-11]. The formation and spread of fine dust negatively affects the environment [12-14]. One of the significant adverse factors is considered to be the occurrence and development of occupational diseases associated with the deposition of fine dust in the lungs of employees [14-16].

The crystal structure of graphite is formed by layers of meshes that are relatively weakly connected to each other. This causes anisotropy of physical and mechanical properties along parallel and perpendicular directions with respect to the surface of graphite flakes. This feature of graphite causes the formation of small particles of carbon-containing materials at all stages of processing [17]. To reduce the impact on employees of the level of dust, a number of measures are proposed, the most widely known are wetting the dusty areas with specially developed compounds [18, 19]. Due to its
specific layered structure, carbon exhibits high antifriction properties [20-23]. It is actively used in various lubricating compositions.

In the conditions of industrial production, there is a danger of carbon dust deposition on the surfaces of the working room-floor, equipment. In addition to the fact that carbon dust deposited on the surface can be lifted into the air by the impact of an air push, there is also a risk of slipping, falling and injuring workers. However, until now, the scientific literature has not paid enough attention to the problem of sliding objects on a horizontal surface, with a layer of carbon deposited.

The purpose of this work is to study sliding in conditions where carbon dust is found on a horizontal surface.

2. Methods
To study the processes that occur when an object slides on a horizontal surface containing a layer of coal dust, similar to the "sole-floor" system, you should evaluate the coefficient of friction. This value is used in many cases for research and analysis of Shoe slip.

During the test, a tile was used as a support surface. Part of the sole of a special Shoe was placed on a tile and, slowly lifting the tile, determined the angle at which the movement of the Shoe sample begins. The sole and surface of the tile were specially prepared: cleaned before testing or applied a layer of graphite, rubbing into the surface. The studies were performed under various conditions: a clean Shoe sample and a clean surface, a Shoe sample and a surface contaminated with graphite dust. A graphite electrode powder with a grain size of no more than 0.1 mm was used as graphite dust. Graphite was applied to the tile surface in the form of a loose layer, or with a small seal.

The weight of the sample sole with a load attached to it was 600 g.

During the experiment, the angle of the tile was fixed. Then the friction coefficient (μ) was calculated using the formula (1).

\[
\mu = \tan \alpha_0
\]  

3. Results and discussion
As you know, the friction force is the force that occurs when the surfaces of two bodies touch and prevents their mutual movement. The friction force is calculated using the formula (2):

\[
F = \mu \cdot N
\]

where \( \mu \) is the coefficient of friction and \( N \) is the reaction force of the support.

The coefficient of friction depends on the nature and condition of the rubbing surfaces.

It is considered that for comfortable and safe movement, the coefficient of friction between the sole of the Shoe and the floor surface should be within 0.5-0.7. Increasing the coefficient of friction contributes to a more stable position of the object on a horizontal surface. On the contrary, reducing the value of the coefficient of friction leads to slippage of the contacting surfaces relative to each other. In the case of the "sole-floor" system, an insufficiently high value of the coefficient of friction can lead to a fall and injury to workers.

To determine the coefficient of friction at rest, consider the movement of a body on an inclined surface of a tile that simulates the floor surface. With a slow increase in the angle of inclination of the plane, you can find an angle \( \alpha_0 \) (Fig. 1), at which the sample will move abruptly and begin to slide along the plane.
Figure 1. Diagram of sliding shoes on an inclined surface.

For model tests, a 5x5 cm sample cut from the toe of the shoe sole was used. Slide shoe inclined surface, covered with graphite dust, as shown in Fig. 1.

The results of calculating the coefficient of friction depending on the conditions of the experiment are presented in table 1.

|                      | Clean floor surface | Compacted graphite on the floor surface | Loose graphite on the floor surface |
|----------------------|---------------------|-----------------------------------------|-------------------------------------|
| Clean Shoe sole sample | 0.58                | 0.56                                    | 0.47                                |
| Shoe sole contaminated with graphite | 0.54                | 0.49                                    | 0.44                                |

The highest value of the coefficient of friction is observed for a clean sample on a clean surface. Contamination of the surface of the sample sole or floor leads to a decrease in the coefficient of friction.

According to the results obtained, there was a decrease in the coefficient of friction between the shoe sample and the surface by an amount of 6-12% in all cases when the sample is contaminated with graphite dust. The presence of a graphite layer on the surface reduces the coefficient of friction by 3-9 % (if the graphite is compacted) and 19% (if the graphite is loose). Apparently, the compacted layer of graphite has a roughness that leads to contact between the sole and the floor. A loose layer of graphite on the surface is characterized by the lowest values of the coefficient of friction. This is due to the possibility of sliding graphite particles relative to each other in addition to the displacement of individual layers of graphite when the structure is destroyed.

Based on the results obtained, recommendations can be formulated to improve the safety of working conditions in production associated with the formation of graphite dust: first of all, attention should be directed to maintaining the cleanliness of the sole of shoes and removing a loose layer of dust. This will help reduce the risk of workers slipping and prevent possible accidents related to falls.

4. Conclusions
Analysis of the results shows that the highest coefficient of friction occurs between a clean Shoe sample and a clean floor surface, which is difficult to achieve in real production conditions. This combination is the safest in production conditions.

The lowest coefficient of friction is obtained when a Shoe sample contaminated with graphite slides when there is a loose layer of graphite on the floor surface. This leads to the conclusion that it is necessary to clean the floor surface and shoes from carbon dust to ensure a safer environment for production workers in the presence of carbon-containing dust in the air of the working area.

The results obtained can be useful for developing recommendations on the organization of safe working conditions at enterprises associated with the processing of carbon-containing materials.
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