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Influence of Emergency Braking on Changes of the Axle Load of Vehicles Transporting Solid Bulk Substrates

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Abstract

When flowable solid bulk commodities are transported, their distribution in a vehicle cargo space may change due to a dynamic load, mainly due to intensive braking. This cargo movement causes changes of a load of particular vehicle axles, what may result in overloading of axles mainly in a front part of vehicle/combination, although the vehicle/combination was loaded correctly. This article quantifies the influence of intensive braking on axle load changes during a transport of cement and selected types of gravel. It is based on practical braking tests which were done for purposes of the quantification of this influence.

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Keywords: solid bulk substrates, cement, gravel, angle of repose, transport, braking tests, vehicle axle load

1. Introduction

When flowable solid bulk substrates are transported, their distribution in a vehicle cargo space may change due to inertial forces related with a vehicle movement, mainly due to intensive braking. This cargo movement causes changes in a load on particular vehicle axles. If a vehicle is evenly and fully loaded and the load of the vehicle axles is close to a maximum allowed weight for the actual type of vehicle/combination, inertial forces acting on the cargo

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during transport may cause cargo movement in the vehicle cargo space (mainly forwards during braking), which results in lowering of load on some axles (rear axles/rear tri-axle of semi-trailer) and overloading of the other axles (mainly front axle/driving axle of a tractor as well as overloading of entire tractor). Therefore mainly the axles in a front part of a vehicle/combination may become overloaded during a transport without any fault of a driver or loading personnel. Flowable bulks may also move rearwards, e.g. when a vehicle accelerates uphill or when a rearward driving vehicle brakes strongly.

2. Teoretical background

A flowability allows typical ways of handling with solid bulk substrates. When a solid bulk substrate (powder or granular) is poured onto a horizontal base, a conical pile will form. The particles are held together by friction forces. The friction forces depend on a shape, size and roughness of the particles as well as on a quantity and character of admixtures. These characteristics are considered in an internal friction coefficient of solid bulks μ_i. Forces acting on a particle of solid bulk substrate in equilibrium are presented in following Fig. 1.

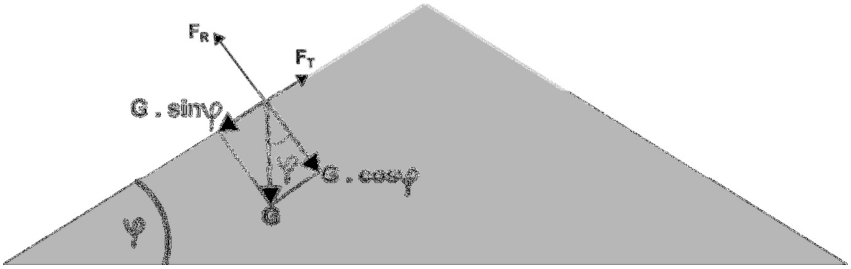

Fig. 1. Forces acting on a particle of solid bulk substrate in equilibrium. Source: authors.

An internal friction coefficient is related with an angle of repose. All forces acting on a particle of solid bulk substrate have to be in equilibrium, because the particles do not move. A force of gravity is spread in a rectangular coordinate system into the forces $G \cdot \sin \alpha$ and $G \cdot \cos \alpha$ in a rectangular coordinate system. A friction force F_T is defined as a product of a perpendicular force acting on a particle and a friction coefficient of a particle on an inclined plane μ_i. This is also applied for an internal friction coefficient of a solid bulk substrate, where a friction force can be defined as $F_T = G \cdot \cos \varphi \cdot \mu_i$. When the forces $F_T = G \cdot \sin \varphi$ are in equilibrium, it can be expressed as follows [1]:

$$G \cdot \sin \varphi = G \cdot \cos \varphi \cdot \mu_i \, . \quad (1)$$

Where the following formula applies for the internal friction coefficient:

$$\mu_i = \frac{G \cdot \sin \varphi}{G \cdot \cos \varphi} = \text{tg}\, \varphi \, . \quad (2)$$

A mutual contact among a large quantity of particles of different shape and size which contact by various different contact surfaces under various angles occurs in relation with the internal friction of solid bulk substrates. The internal friction coefficient uses to be higher than the friction coefficient between two straight surfaces of the same material. If a solid bulk substrate is more compact (its volume weight is higher), its internal friction is higher. However, the substrate volume weight may change during a skid, so the internal friction coefficient may change in time [2].

An angle of repose decreases due to vibrations and oscillations of a base during a movement (e.g. transport) and so called dynamic angle of repose (φ') is created. The angle of repose related with the dynamic internal friction may be approximately expressed from the natural angle of repose as follows: