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CONTINUOUS HANDLING

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SPECIFIC CHARACTERISTICS OF BULK PRODUCTS AS APPLICABLE TO STORAGE IN SILOS

Determination and representation of flow characteristics

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1 - INTRODUCTION

This document is a part of the document FEM 2 581 "Characteristics of bulk products" and is in close relation with the document FEM 2 582 "General characteristics of bulk products with regard to their classification and their symbolization".

Beside the general characteristics indicated in this document, the flow properties of bulk products and their dependence on particular marginal conditions must be taken into consideration when storing bulk products in silos.

This document describes the specific characteristics of the products and outside influences which come to bear on them, as well as the representation of these characteristics, particularly when they are measured by shear tests.

2 - FOREWORD

When designing a silo for storing bulk products, the characteristics of the product play a fundamental role, particularly for :

- the geometry of the silo (shape, dimensions, capacity)
- the function of the silo (flow profile, outflow behaviour, operating conditions)
- the structure of the silo (stresses exerted on the silo structure).

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In order to do this, it is necessary to identify the flow behaviour of the bulk product. The flow properties of products are not constant, but depend on various factors, particularly on the compressive stress exerted upon the product before and during flow.

3 - DEFINITIONS

We can summarize as follows the flow properties when storing the bulk products in silos which are important to determine the behaviour of the product and to consider it in the design :

- The wall friction angle φ_w as a function of the compressive stress σ_w between product and wall.
- The bulk density ρ_b as a function of the major principal stress σ_1 in the product.
- The internal friction angle φ_i of the product incipient failure, as a function of the maximal principal tension σ_1 (or as a function of the corresponding product bulk density ρ_b).
- The internal friction angle φ_e of the bulk product at steady state (so-called effective friction angle) as a function of the major principal stress σ_1 in the product.
- The compressive strength σ_c of the product as a function of the major principal stress σ_1 in the product.

Each element of the stored bulk product is in a three-dimensional stress condition.

For a graphical representation of the state of stress, we use the Mohr's circle in a σ,τ-graph ; it suffices to consider a plain strain condition with σ_1 as the greatest and σ_2 as smallest principal stress. In powder mechanics, compressive stresses are assumed positive.

During steady state flow the bulk product flows without change in volume, i.e. during steady state flow the bulk density ρ_b remains locally constant.

4 - DETERMINATION, DESCRIPTION AND GRAPHICAL REPRESENTATION OF FLOW PROPERTIES

The above-mentioned flow properties cannot be directly measured, but must be indirectly determined by shear tests, the results of which can be derived graphically or by computation.

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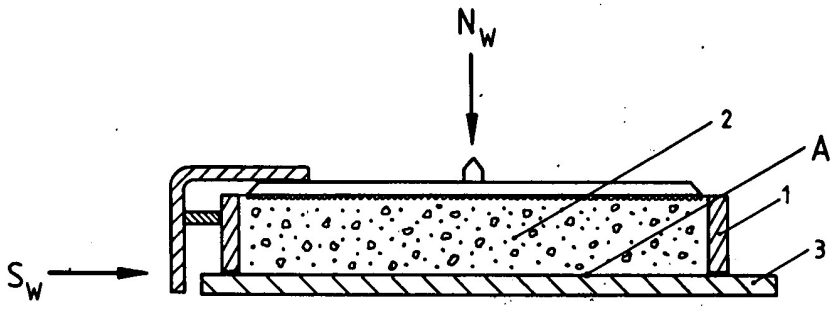
The determination of flow properties of bulk products from shear tests was introduced by A.W. Jenike, who also developed a shear tester. Such tests are very long and complicated, and we describe only the basic principle. A detailed description of the measuring method according to Jenike is being prepared with the "Standard-Shear-Testing-Technique" (SSTT) by the "Working Party on the Mechanics of Particulate Solids" (WPMPS) of the "European Federation of Chemical Engineering" (EFCE) and will be available probably in 1986. Besides, other similar shear testers exist, e.g. rotational testers.

4.1 - Shear tests to determine the wall friction angle

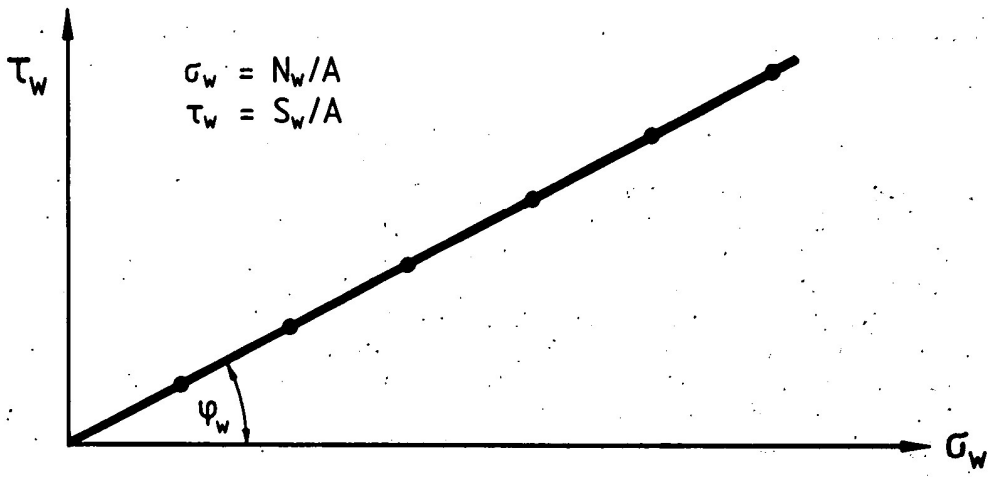
Determination of the wall friction angle φ_w is very simple. Using a shear tester, e.g. the Jenike shear tester (fig.1), we can measure the shear force S_w necessary to shift, against a flat surface made of wall material (3), the bulk product (2) being placed in a shearing ring (1) and subjected to a normal force N_w exerted from the top.



top : Shear test to determine the wall yield locus (according to Jenike)

Figure 1

bottom : wall yield locus



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