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Research on the Flow Behaviour of Bulk Materials at the University Essen

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Materialflußtechnische Untersuchungen mit Schüttgütern an der Universität Essen — Gesamthochschule
Projet de recherche sur l'aptitude à l'écoulement de matières en vrac à l'Université de Essen
Proyecto de investigación sobre el comportamiento de flujo de materiales a granel en la Universidad Essen

エッセン大学におけるバラ材料の流れ特性の研究

埃森大学松散材料输送过程研究

أعمال البحث في مجال سلوك وظواهر تدفق المواد السائبة في جامعة ايسن.

1. Introduction

Teaching and research in the materials handling department at the University of Essen concentrate on continuous conveyor systems and, within this category, more particularly on the mechanical handling of bulk materials and unit loads. In addition, storage technology for bulk materials is studied (Fig. 1).

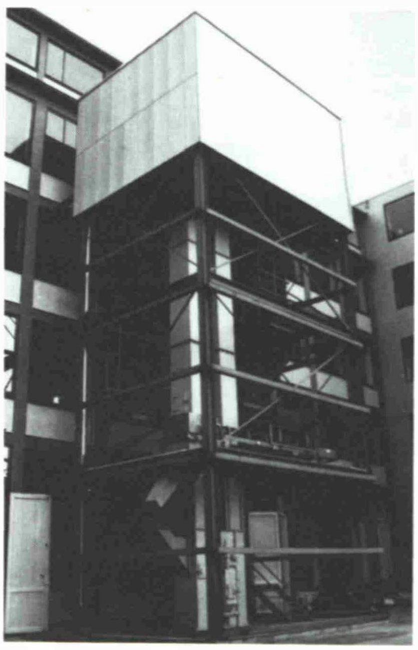

Fig. 1: General view of the experimental installation

In connection with material flow engineering problems, special interest is focused on a closed-circuit bulk handling installation which has been constructed for carrying out a research project promoted by the Ministry for Science and Research of the Federal German State of Nordrhein-Westfalen. The object of this project is to determine, by means of theoretical and experimental investigations, the precise conditions of centrifugal discharge of bucket elevators. Further aims are to develop forms of elevator bucket of the basis of the results obtained and, alternatively, to test known bucket designs with regard to their fatigue strength. In addition, the validity of the currently applied design principles for bucket elevators is to be verified.

2. Experimental Plant Layout

Because of the realistic layout and design of the whole installation, closely simulating conditions in actual practice, this experimental research project is of major importance.

With reference to Figs. 2 and 3, the experimental installation comprises a bucket elevator (1) which discharges into a hopper (2) from which the material is removed by a vibratory conveyor (3). The latter deposits it on a belt conveyor (4), equipped with a belt weigher, which discharges it into an inclined

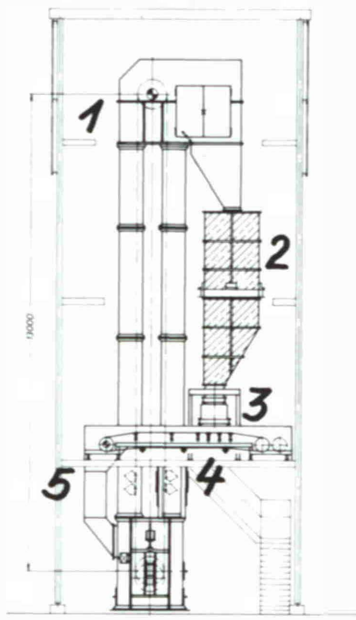

Fig. 2: Drawing of the experimental installation: (1) bucket elevator; (2) *Flexilo* hopper; (3) vibratory conveyor; (4) belt conveyor; (5) inclined chute

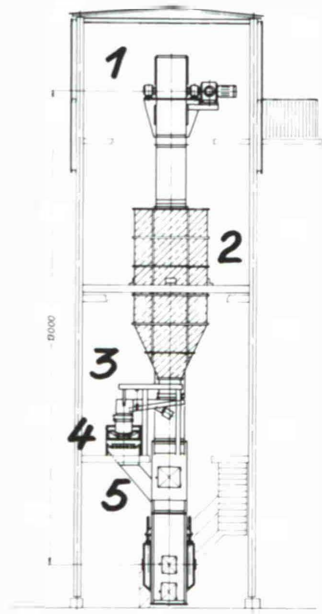

Fig. 3: (see Fig. 2)

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chute (5) that feeds it into the inlet of the elevator. This chute, like the one feeding the material from the top of the elevator into the hopper is lined with wear-resistant elastic material in order to reduce noise emission (Fig. 4).

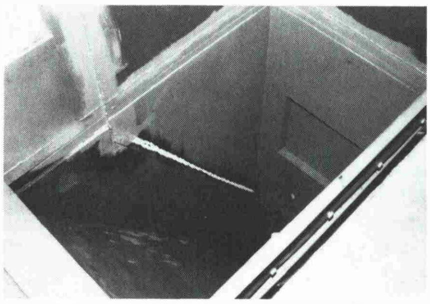

Fig. 4: PVC-lined receiving hopper at the elevator head

Although research work is at present concerned mainly with the bucket elevator, it is also yielding a considerable amount of information and measured data relating to the hopper. It is intended subsequently to carry out research concentrating more particularly on the hopper system.

Where characteristic data are given in this preliminary report, e.g., relating to the elevator, this has been done only with a view to indicating the possibilities available for experimental research also on hoppers and bunkers.

The experimental bucket elevator designed and supplied by Aumund-Fördererbau GmbH, Rheinberg, is of the double casing type, i.e., the carrying run and the return run are in separate casings. The overall height is 15 m and the centre-to-centre distance 13.5 m.

The elevator head is accommodated in a measuring room — an enclosure in which measurements and observations relating to the discharge of the material from the elevator buckets can be carried out at all times, independently of external influences. For this purpose the elevator head assembly is provided with observation ports and a large observation opening closable with double doors (Fig. 5).

The buckets are mounted on a steel cord belt with its ends joined by mechanical fasteners. It is a transversely reinforced belt supplied by Kléber. Its quality designation is *Metallcord 1600*. Characteristic of this elevator is the close spacing of the buckets, an arrangement which achieves high handling capacity in conjunction with relatively favourable dimensions of the elevator and with low bucket filling losses (high bucket load factor).

All the buckets are of the same shape, i.e., the opening angle and projection distance are at present identical for all of them. On the other hand, the buckets

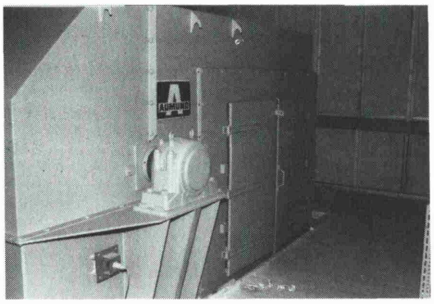

Fig. 5: Measuring room with elevator head and large observation opening

differ in their constructional features. For instance, two types are currently being used. One of these is a very light bucket with strengthened front edges, the other is a highly wear-resistant form of construction with strengthened edges.

The elevator is driven by an AEG DC motor with infinitely variable (stepless) speed control providing a belt speed range from 0 to 2.51 m/sec. The drive power rating is 22 kW (Fig. 6). For a belt

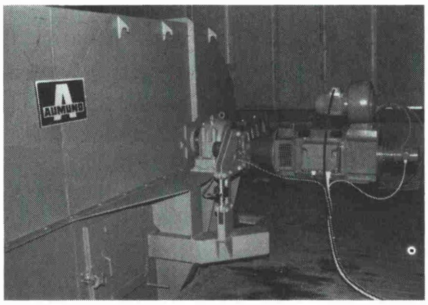

Fig. 6: Measuring room with elevator head (drive side)

speed of 1.73 m/sec the elevator attains a handling rate of about 260 t/h. This is also the maximum hourly throughput rate for the hopper installation. The hopper is a *Flexilo* supplied by Dr. Nordmann KG, Essen. It is characterized by a steel open framework provided with an internal liner of fabric-reinforced special rubber. In principle a *rubber wall* of this kind is similar in construction to a conveyor belt with textile carcass. The material is either bonded with adhesive to the steel members of the hopper frame or is — as in the experimental installation described here — secured only at the corners of the hopper with the aid of so-called *Hermetic* hinge fasteners of clamping strips (Fig. 7).

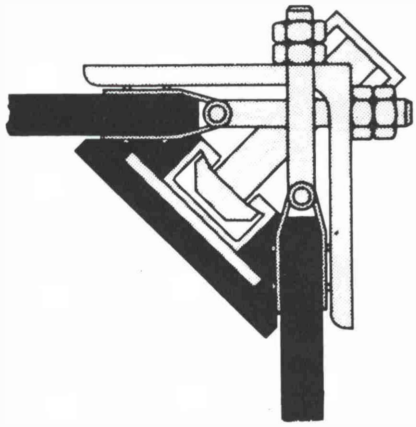

Fig. 7: Attachment of liner with clamping strips

The grade of rubber wall material used in this hopper has the designation EP40 and is rated as highly wear-resistant. It has a smooth interior surface so as to prevent sticky material from adhering to it. With its thickness of 10 mm this wall, designed to close the panel openings between the members of the supporting framework, is sufficiently elastic to ensure a high degree of flexibility. Any bulging of the wall in one panel will automatically cause the wall in adjacent panels to be pulled taut (Figs. 8

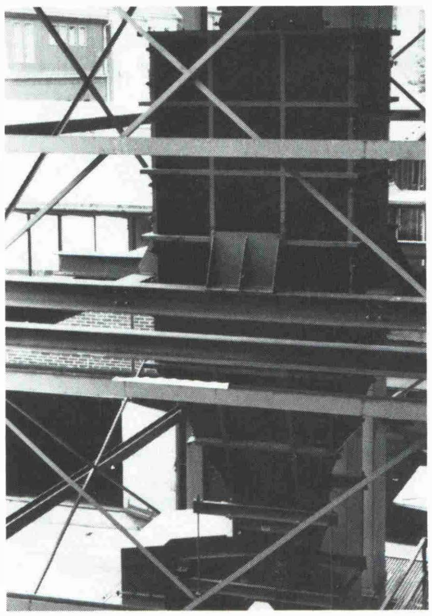

Fig. 8: *Flexilo* (steel-frame hopper with open framework and rubber walls): outlet portion

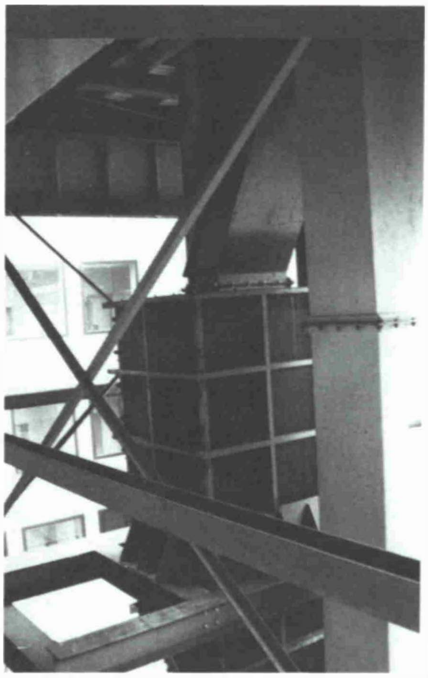

Fig. 9: Inlet portion of the *Flexilo*

and 9). The resulting differences in tension of the *Flexilo* wall will — for example, during emptying of the hopper — be distinctly visible from the outside as movements of the wall. In this hopper, in which the rubber lining is secured only at the corners and is thus freely movable on its framework, relatively very large differences in tension may thus occur.

This behaviour enables the rubber wall to perform *working movements* of considerable magnitude, so that any *arching* or *bridging* of the material is immediately broken up and cohesive material is moreover prevented from sticking to the wall and from thus adversely affecting the emptying process, as is liable to accur with other types of hopper.

As appears from Figs. 2 and 3, the outlet of the *Flexilo* is not of axially symmetric design. Its side facing the bucket elevator is entirely vertical. This could in itself be expected to achieve good discharge conditions for the hopper contents, because only in this way is it (viewed on cross-section of the hopper) possible to obtain different discharge rates and thus correspondingly different flow profiles and stresses in the bulk material, which are essential to trouble-free operation.

In combination with the *Flexilo* flexible wall system a hopper has thus been constructed which forms a particularly vital element in terms of material flow behaviour within the overall experimental installation, since it is a well known fact that operational trouble due to cohesive bulk materials is always most likely to arise in hoppers, bins or bunkers.

The decision to use an optimally reliable, though expensive, solution has so far proved to be a correct one. At the present time, gravel with low abrasion resistance and approximately 10 mm maximum particle size is being used as the test material. It was fed pneumatically into the installation from a tanker vehicle. Already at the time of writing, the test material has been found to have a high content of fine and very fine particles, causing considerable dust formation at the bucket elevator head. The proportion of dust in the material can be estimated at about 5% of the total load in the handling circuit (approximately 14 t). More precise measurements are to be carried out shortly. As the dust interferes with observations at the head of the elevator and disturbs the measurements that have to be performed, the material is moistened to suppress dust. This added moisture is liable to cause cohesion phenomena which may have a strongly adverse effect on the bulk material flow behaviour.

During the course of the test the proportion of fine particles due to abrasion will increase, and therefore also the amount of dust. This in turn will necessitate spraying more water, so that the shearing strength of the test material will progressively increase too. However, no trouble in operating the handling system has so far occurred. Yet it is to be expected that even with the *Flexilo* equipment it will not, in the long run, be possible to prevent trouble e.g., when the shearing strength of the material will (as a result of abrasive disintegration and the addition of water) have become so high that the buckets can no longer be properly emptied.

As the limits to which conventional hopper or bunker installations can be loaded are known, it will be interesting to determine the maximum load capacity of this type of hopper in relation to the shearing strength of the bulk material passing through it.

The advisability of providing the *Flexilo* with some fairly small air blast injectors is at present under consideration. When this flexible hopper has reached its maximum load capacity with cohesive bulk material, it will then be investigated to what extent the admission of pulses of compressed air is still able to restore such material to a condition suitable for handling and storage.

As the *Flexilo* installation is now still functioning with very good mass flow behaviour although the proportion of fines and the water content have meanwhile risen considerably and the shearing strength of the bulk material has already become quite high in consequence of this, it can be presumed that this very expensive form of construction (as compared with conventional hoppers) justifies such expenditure by its high degree of operational availability.