Digital Weighing in Bulk Handling

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Digitales Wiegen in der Schüttgutfördertechnik
Pesée numérique dans la mécanutention de matières en vrac
El pesaje digital en la tecnologia de transporte de materiales a granel
バルクハンドリングにおけるディジタル秤量
散庄处理数字称重
الوزن الرقمي في مجال مناولة المواد السائبة

Summary
A general introduction to weighing in bulk handling is given with particular reference to the various methods of weighing bulk materials during and after loading. Several case studies are outlined.

1. Introduction

In a relatively quiet way, weighing technology has advanced rapidly and dramatically in recent years. Two decades ago the weighing industry was on the verge of proving electronic weighing a viable concept. Today, it exploits the latest solid-state techniques in all manner of weighing equipment, and it does so with facility and sophistication.

This can largely be attributed to strong and traditional innovatory instincts. Accustomed to lively product-development programmes, weighing research and engineering teams have been quick to see that electronics can lead to major improvements in product performance, quality and reliability.

The process has been going on for some time, longer than many people realize. The first load-cell weighbridges were installed in the early 1960s and are as commonplace nowadays as their mechanical counterparts were twenty years ago. Before the seventies, static digital instrumentation was being incorporated in load-cell systems for process weighing, and the first electronic scheme for weighing rail wagons in motion was in service.

The microprocessor is the most recent influence, and in the last four years the pace has quickened.

The *chip* has swept away certain technological restrictions on product specification and performance. It has freed weighing designers and engineers from the restraints imposed by past technologies.

Microprocessors, microcomputers, and the allied control and programming techniques are now being used in all types of equipment, from counting machines and industrial scales to weighbridges, batching systems and weighing-in-motion installations. Thus load cells, solid-state physics, digital techniques, computer technology, and control engineering have come into alliance with the advanced mechanical engineering on which successful weighing will always depend.

This paper considers how the current technology is being applied to two different methods of weighing bulk materials — during and after loading.

2. High-Speed Loading Out

At the British Steel Corporation's new Hunterston terminal in Scotland an advanced and extensively automated bulk-loading station is now in service for delivering iron ore and coal by rail to the Ravenscraig steelworks.

Built by Adamson Butterley Ltd., the station handles both materials on fully automatic sequences, loading-out up to 3000 t/h. Typically, it can discharge 1600 t of ore into a train of twenty-one wagons in less than thirty minutes.

2.1. Two Weigh Systems

The coupled wagons are filled from overhead hoppers, the ore or coal being weighed in the hoppers by electronic systems engineered to deliver preset loads on repeating cycles. Digital and load-cell based, these systems were designed and built by W&T Avery Ltd., which had previously supplied similar, though less sophisticated, equipment for bulk-loading stations at other BSC plants. Their primary task is to measure out accurate wagon loads and record the net weights carried by each wagon, and the whole train.

Straddling three rail tracks, the portal loading-out station contains two load-cell weighing systems, one for ore and the other for coal. Both are stamped for trade use. They are essentially similar in design, the only important difference being that the ore weighers are sequenced to fill wagons in groups of three and the coal weighers in groups of four.

2.2 Ore Weighing

Ore is weighed into six hoppers from a 3500 t capacity bunker suspended over one of the rail tracks running through the station.

This system consists of six 40 t capacity load-cell weighers (one for each hopper) with common digital instrumentation and printing equipment. The weigh instrumentation is integrated into the station's control circuits and interlocked with wagon-positioning sensors. It generates signals to regulate hopper loading and discharge, to operate console-mounted dial indicators and the common digital display, and to record the net weights loaded into the wagons and the train as a whole. The six weighers operate in adjoining pairs, two hoppers to each wagon, but discharge simultaneously.

2.3 Coal Weighing

Located above the other loading-out track, the coal weighing system works

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in much the same way but consists of four 40 t capacity load-cell weighers, each supporting one hopper beneath a 2500 t capacity bunker.

2.4 Positioning Wagons

The operation of both weighing schemes is monitored on consoles and mimic boards.

When a train arrives for loading on the centre track, it is identified as *ore* or *coal*, switched onto the appropriate side track and the diesel locomotive uncoupled.

If it is an *ore* train, an automatic hydraulic shuttle positions the first three 76 t capacity wagons under the hoppers. The 31 t capacity coal wagons are positioned by a rope-hauled beetle system running between the rail lines. Normally, there are twenty-one wagons in an ore train and up to thirty in a coal train.

2.5 Two-Stage Hopper Filling

Trackside proximity switches and light sensors notify the control circuits when the wagons are correctly positioned.

Interlocks clear and the plant operator starts discharge from the bunker into the hoppers, each of which is carried on four 50 t capacity load cells. A signal from the discharge control to the weigh circuits initiates the weighing and printing cycle.

As the loads in the hoppers increase, the weights register continuously on dial indicators on the main console. When they reach values preset on trip amplifiers, weight-related signals slow the feed to dribble and, at the required weight, stop feed altogether. If required, the hopper loads can then be checked by switching the common digital display between the three pairs of weighers in the ore weighing system, or to any individual weigher in the coal system.

2.6 Weight Storage

When the feed stops and the weight signals are steady, the instrumentation scans the weigher outputs in rotation, so that the print-out will correspond to the wagons' position in the train, and stores the gross weights. It then signals that the hopper doors can be opened. Provided safety interlocks have cleared, the material is discharged into the wagons from all hoppers simultaneously.

When the hoppers are empty and the doors closed, the weigh instrumentation reads the hopper tare weights (again in rotation) and subtracts them from the gross weights to determine the net weights loaded-out. These values are printed and stored.

A signal from the instrumentation then instructs the control circuits to move the next group of empty wagons into position. The loading cycle is repeated.

When the train has been loaded, a clearance signal initiates print-out of the net weight in all wagons, together with date and time.

2.7 Safeguards

Several interlocks have been built-in to ensure safe, reliable operation. The hoppers cannot discharge until the feed has stopped and the weights have been stored. Discharge is also inhibited until track switching has proved that the wagons are properly in place under the hopper outlets. Similarly, a second operation of the hopper doors is prevented until a set number of wheels has been counted past the loading positions.

If less than three ore wagons remain to be loaded at the end of a train, proximity switching at the approach rails allows only two or four hoppers to be filled. Fail-safe devices also prevent the hopper doors opening if there is a power failure.

Further safeguards in the weigh instrumentation include interlocks to stop feed if a hopper exceeds a given weight, and two separate sets of printing equipment (one duty and one stand-by) controlled by separate circuits.

In an emergency, the station can also be operated semi-automatically by pushbuttons.

3. Weighing-In-Motion Under Microprocessor Control

Weighing-in-motion has been employed for determining wagon weights, chiefly by the extraction, power and metal industries, for several years. It is mostly used for weighing trains of coupled rail wagons, the in-motion speeds ranging upwards from 1/2 mile/h to 8 mile/h and more.

The advantages of in-motion weighing are obvious. It is capable of realizing dramatic time and cost savings. By comparison with conventional static methods, it saves the laborious business of stopping and perhaps uncoupling wagons for weighing.

In its latest form, an in-motion weighing system consists of a load-cell axle weigher, which is installed in the rail track, and digital electronic instrumentation incorporating a digitizer, digital display and printer. The instrumentation also includes one or more microprocessor control units to filter out low-frequency vibrations, operate automatic zeroing circuits and control the whole process of weighing, display and recording.

The microprocessor is relatively new to this duty. Its main assets in the role are dependability and flexibility. It can readily be programmed to provide additional or alternative facilities without any need for extra circuitry.

3.1 Up to 5 mile/h

An Avery system of this type has recently entered service at the NCB's Cadley Hill Colliery near Burton-on-Trent, England for weighing coal wagons ranging in net capacity from 13.5 to 32 t each.

Stamped for use in trade, it weighs coupled two-axle wagons of various types while they are running at up to 5 mile/h. It sums the two axle weights to arrive at the total wagon weight, which is subsequently printed-out automatically against a number representing the wagon's position in the train.

Although designed for continuous twenty-four hour service, the system is used mainly between 7 am and 8.30 pm. In a week, it weighs between 250 and 270 wagons, most of them coupled into runs of four to ten wagons. Much of the coal is delivered to CEGB Drankelow, which accepts print-out weights from the system as the basis for NCB invoices.

Trains can approach the system from either direction. Track switches on the lead-on rails on both sides of the weighing position detect the train's approach.

The run of wagons is either hauled by a locomotive or manually controlled down a gentle incline. If a locomotive is used, when its first axle reaches one of these switches, the system's automatic zero-balance circuitry is locked and the system set for weighing.

Other track switches are mounted at the weigher to identify axles as they cross the weighing platform. These switches ensure that the locomotive, is recognized by its three axles and ignored by the instrumentation.

All track switching is monitored by a second microprocessor unit, which also manages the overall control of the system.

The use of two microprocessors, instead of the one in earlier systems, ensures a better structured program and improved flexibility.

3.2 Sized to Suit

The load-cell axle weigher is 1.6 m long, a dimension selected to ensure that, whatever the wagon type, only one axle is on the weigh platform at any time. Accuracy in in-motion weighing has two enemies, the high and low-frequency vibrations created as the axle runs over the platform. The high-frequency components are attenuated by careful mechanical design of the structure and an internal filter network.

Low-frequency vibrations, which can have a more serious influence, are attenuated by a microprocessor-based digital filter. This produces a precise calculation of weight during the passage of the axle by sampling and averaging several weighings taken at intervals related to a specific mathematical formula. This *steady* axle weight is then memorized. The second axle is weighed similarly and its weight stored.

3.3 Print-Out

When all wagons in the run have cleared the system, the stored axle weights are automatically summed in pairs to provide total wagon weights, and combined with date and time information. A tally roll print-out in triplicate then gives all the coded wagon weights plus the total train weight with date and time.

The system, which has an in-motion capacity of 60 t, indicates dynamic weights on a seven-segment display reading in 0.01 t intervals. It is equipped with an alpha-numeric keyboard for inserting train data and controls to warn when wagons travel over too fast, to test displays, to reset the system, etc. An additional display is provided for use when the system is weighing statically.