CONTINUOUS BELT WEIGHING

JOHN DRONETTE, SIEMENS, USA, EXPLORES THE ROLE OF CONTINUOUS BELT WEIGHING DEVICES IN THE CEMENT INDUSTRY, AND EXPLAINS BEST PRACTICE INSTALLATION, CALIBRATION AND MAINTENANCE.

Introduction

Continuous weighing devices such as weigh feeders and conveyor belt scales are critical to optimising production, quality and inventory in a cement plant. These scales respond to vertical forces, both desirable and undesirable. Many issues can be a result of problems with the conveyor, incorrect commissioning or maintenance leading to undesirable forces influencing repeatability and accuracy. Careful evaluation of the application, proper installation, calibration and routine maintenance will yield many hours of continuous and reliable service. This article addresses the proper application, use, and maintenance of continuous weighing devices, and demonstrates these by providing examples from the cement industry.

Conveyor belt scales and weigh feeders are important equipment in cement plants. Belt scales and weigh feeders are frequently used to help control inventory, maximise raw materials usage and aid in producing a consistent product. Correct installation and maintenance are required to achieve this.

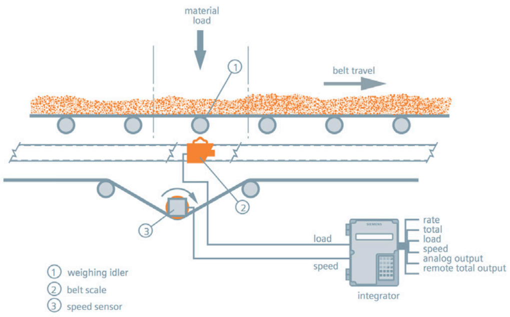

Figure 1. A belt scale integrator uses the signals from the weigh bridge and speed sensor to calculate the flow rate and calculate an accumulated weight.

Understanding the theory behind it all

Conveyor belt scales use a weigh bridge to continuously measure the load on a conveyor belt – and a sensor to determine its velocity. A belt scale integrator uses the signals from the weigh bridge and a speed sensor to calculate the flow rate and accumulate a total weight. The integrator then provides a usable output to the operator or control system in the form of analog and discreet outputs or bus communication.

Weigh bridge

A conveyor belt scale weigh bridge is a frame that is installed in the conveyor at the location of an existing idler. The idler is then mounted on the weigh bridge. The weigh bridge uses one or more load cells, so as weight is applied to the idler, it is transferred through the idler to the load cell(s). The load cell(s) provide an output signal that is directly proportional to the gravimetric load on the conveyor belt.

Speed sensor

Conveyor belt scale speed sensors come in a variety of mounting configurations. Shaft-mounted speed sensors are connected to the shaft of the conveyor's tail pulley or to the shaft of a bend pulley. Trailing arm or return belt speed sensors use a wheel that is mounted so it is always in firm contact with the return strand of the conveyor belt. The output signal of the speed sensor is proportional to the speed at which the pulley or wheel is rotating. The belt scale integrator can calculate the belt speed based on the diameter of the pulley or wheel and the speed at which it is rotating.

Belt scale integrator

Most modern conveyor belt scales use microprocessor-based integrators to combine the signals from the weigh bridge and speed sensor to calculate material flow rate based on the following formula:

Flow rate = belt load x belt speed

In applications where the belt scale is used for batch blending or inventory control, the accumulated total may be more useful than flow rate. A belt scale integrator uses the following formula to calculate the accumulated load:

Accumulated weight = belt load x length of belt travel

Belt scale installation

As in real estate, location is a major consideration when installing a belt scale. While location on the conveyor is a primary concern, the type of conveyor that is most suitable for a belt scale should also be considered. There are two primary goals when selecting a conveyor and an ideal location for a belt scale: reduce the number of forces acting on the weigh idler and increase the material load transferred to the scale by selecting a location where belt tension is consistent and as light as possible.

Conveyor selection

The principle of operation of load cells is that gravimetric forces deflect them. This deflection is very small, usually a fraction of a millimeter. The conveyor should therefore be rigid so that deflection caused by the material is applied to the load cell and not to the conveyor structure. The conveyor should also be free of excess vibration.

When considering the conveyor, the type of carrying idlers can also affect the performance of the scale. Idlers can be trough idlers or flat roll idlers. Trough idlers use three rollers. The bottom centre roller is flat and the two outside rollers – called wing rollers – are located at an angle, typically of 20˚, 35˚ or 45˚. The wing rollers are designed to turn up the edges of the conveyor belt to contain material on the belt. Idlers with trough angles of 20˚ and 35˚ are very common, and are well suited for conveyor belt scales. As the edges of the belt are turned up, the belt becomes stiffer therefore allowing less of the material load on the belt to be transferred to the weigh bridge. This is the reason that belt scales installed on conveyors using idlers with trough angles of 45˚ may have a slightly lower accuracy. Other idlers that are well suited for conveyor belt scales include picking and flat roll idlers.

Other idler types, which are not as well suited for conveyor belt scales, include impact, adjustable transition, spiral catenary and wire rope idlers.

Training idlers are another idler type commonly found in the cement industry. It is common to have one to three training idlers on the carrying side of the conveyor. Training idlers have guide rollers on the side of the idler to keep the belt from moving past the outside edge of the idler. Training idlers also pivot in the centre of the idler. If the belt starts to move to the right side, the training idler will start to pivot, moving the right side of the training idler forward, pushing the belt back to the centre. Training idlers are usually installed so their centre roller is about 25 mm – 50 mm above the centre roller of the other idlers. As training idlers subject

Table 1. Minimum recommended distance from the end of the infeed skirtboards to the scale	
Belt speed	**Distance**
Up to 1.5 m/sec	2 m
Up to 2.5 m/sec	3 m
Over 2.5 m/sec	5 m

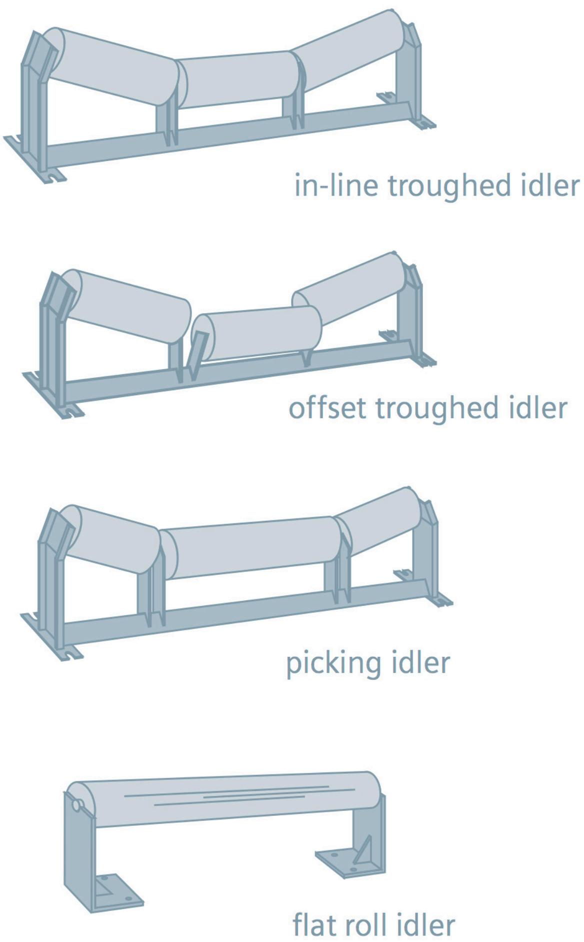

Figure 2. Idlers that are well suited for use with a conveyor belt scale.

the belt to a wide range of varying forces near the idler itself, it is recommended that belt scales are installed a minimum of 18 m from a training idler.

A conveyor should be selected where material can be diverted out of the process after being transferred across the belt scale or introduced into the process before being transferred across the scale. This is done to allow the belt scale to be tested with material. This testing process is discussed further in the section on calibration.

Location on the conveyor

As mentioned previously, a conveyor belt scale should be installed at a location where belt tension is the least. Conveyor belts will have more tension near the head pulley than near the infeed. Regarding the load on a conveyor, consider a conveyor that is 100 m long with a material load of 75 kg/m. A point near the drive of the conveyor will be moving a pile of material weighing about 7500 kg. A point 10 m from the infeed will be moving approximately 750 kg of material.

It is best to locate the scale near the infeed, where belt tension is the least. Having said that, the material will need to be given time to settle before it crosses the scale. Table 1 shows the recommended distance from the end of the infeed skirtboards.

If it is not possible to locate the scale near the infeed, then the scale must be located near the head pulley. Care must be taken to minimise the effects of the belt transitioning from the troughed profile of the idler to the flat profile of the head pulley. Conveyor manufacturers align the head pulley higher than the centre roll of the idlers to ease this transition. If a scale is located within five idlers of the head pulley, the head pulley can be no more than 13 mm above the centre roller of the trough idlers. To ease this transition even more, if the conveyor uses 20˚ trough idlers, the scale must have a minimum of three idler spaces between the scale idler and the head pulley. If the conveyor uses 35˚ trough idlers, there must be a minimum of four idler spaces between the head pulley and the scale idler – and the idler closest to the head pulley should have a 20˚ trough. If the conveyor uses 45˚ trough idlers there must be a minimum of five idler spaces between the scale and the head pulley. The idler closest to the head pulley should have a 20˚ trough, and the idler before the 20˚ trough idler, should have a 35˚ trough.

When installing a conveyor belt scale on a conveyor with a curve, the scale should be installed at a location where the curve does not influence the scale performance. Curves can be concave or convex as shown in Figure 3. If the conveyor has a concave curve, the curve will have a lifting effect on the belt in the area of the curve. If this lifting effect occurs in the scale area it will cause the belt scale to output values less than the actual material load. It will also cause the scale to perform in a non-linear manner. To prevent this from affecting the scale's performance, the belt scale should be located a minimum of 12 m from the last point of the curve. A convex curve on a conveyor will tend to pry up the belt near the curve, producing similar accuracy issues to scales installed too close to a concave curve. To minimise the effects of a convex curve in the conveyor, a conveyor belt scale should be installed a minimum of 6 m from the last point of the curve if the scale is on the infeed side of the curve. If the scale is on the discharge side of the conveyor, the scale should be located a minimum of 12 m from the last point of the curve.

Alignment

Idler alignment in the scale area is critical to the accuracy of the scale. A minimum of two idlers on

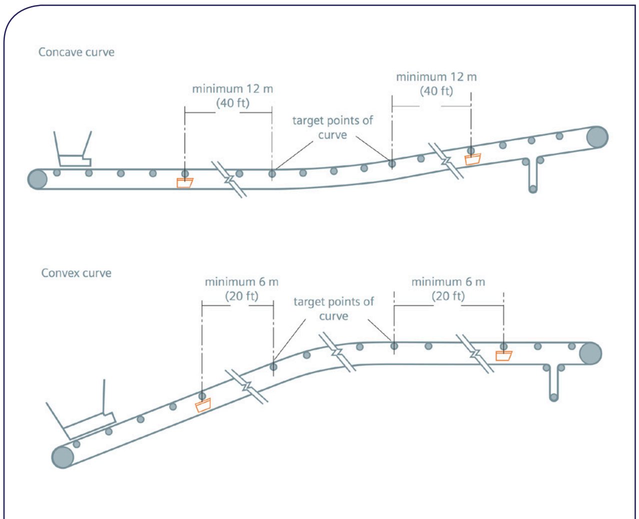

Figure 3. Convex or concave curves need to be considered when installing a scale.

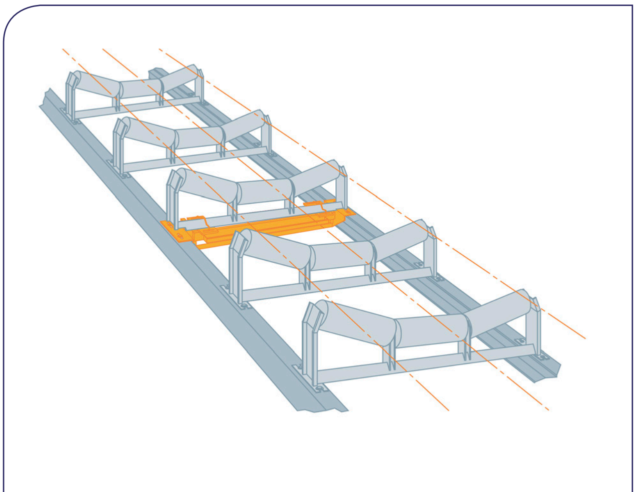

Figure 4. Idlers need to be aligned vertically.

each side of the scale should be aligned in all planes to within 0.8 mm of the scale idler. In some high accuracy applications, 0.25% or better, three idlers on each side of the scale may have to be aligned. To achieve this alignment accuracy, each idler should be spaced equally, squared and centreed on the conveyor frame. The idlers should also be aligned vertically. To vertically align the idlers on a trough conveyor, three nylon strings or 0.5 mm piano wire is stretched across the idlers to be aligned. The string or piano wire should be secured to the conveyor frame and drawn tight enough to prevent any sag. On conveyors with flat roll idlers, two strings can be used, with one string on each side running the length of the idlers being aligned. Shims are added between the idler and the conveyor stringer to bring each idler into alignment.

Best practice installation

Proper scale installation is critical to scale operation. Careful compliance with all of the manufacturer's guidelines when installing a conveyor belt scale is essential. Prior to installation, the suitability of the conveyor for a belt scale and its location on the conveyor must be considered. Whenever possible, the scale should be located closer to the infeed area of the conveyor where belt tension is the least – and areas where the belt may have irregular tension, such as near the head pulley and in curves, should be avoided. Once the scale has been installed, careful attention must be paid to the idler alignment in the scale area.

Whenever possible a conveyor where the belt scale can be tested against a static scale should be selected. A cement producer in the eastern US, when budgeting to install a new belt scale, included the costs to install a diverter valve at the conveyor discharge. This diverter valve could be used to load material into a truck after being transferred across the belt scale. The material could then be weighed on a static scale to test the belt scale accuracy.

Calibration

Calibration methods

There are three common methods of conducting simulated load calibration of a belt scale or weigh feeder: weights, chains and electronically. Electronic calibration induces a bias voltage on the load cell signals to simulate load on the conveyor. This method of calibration does not fully test the scale suspension system. Therefore, it is recommended that this calibration method is only used when access to the scale is restricted. Calibration weights are static weights that are placed on the scale to simulate a material load on the belt. Calibration chains are large roller chains that are pulled onto the carrying side of the belt above the scale and held in place during calibration using chains or cables. There is some disagreement in the industry as to whether test chains provide any significant benefit over static weights. Although both methods are acceptable for simulated load calibration procedures, calibration chains are made up of a series of rollers where additional maintenance may be required to ensure that these rollers can always freely rotate. Further, a calibration chain could become a safety issue if it were to come loose or break during calibration.

In addition to simulated load calibration, it is also recommended that conveyor belt scales be material tested after initial simulated load calibration and whenever significant maintenance is done on the conveyor. Material testing compares the readings from the conveyor belt scale against a known accurate scale.

Repeatability vs accuracy

Before discussing calibration, it is important to understand the differences between repeatability and accuracy. Repeatability refers to the ability to repeat a result multiple times under the same conditions. Accuracy is the ability to repeatedly produce the

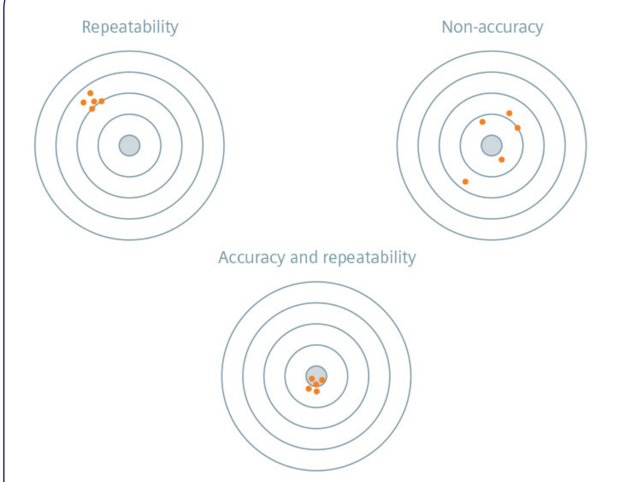

Figure 5. Repeatability and accuracy are two very important attributes.

required result. With the targets in Figure 5, you can see that for the top target, the marks are scattered around the centre with no recognisable pattern. This would represent a scale that is neither repeatable nor accurate. For the bottom left target, the marks are very close together but not in the centre of the target. This represents a situation that is repeatable but not accurate. For the target in the lower right, the marks are grouped close together, and are at the centre of the target. In order to accurately calibrate a scale, you must first establish repeatability before the scale can be properly adjusted. For example, if the first test resulted in an error of 3.25%, no adjustment is made. If a second test is subsequently performed resulting in an error of 1.06%, then this represents a difference of 2.19%. If the desired accuracy is 0.5%, then there is no adjustment that can be made to allow the scale to achieve this accuracy. However, if the second calibration shows a 3.31% error, a difference of 0.06%, an adjustment of 3.28% can be made and the scale will be well within the desired accuracy of 0.5%. This is the reason, that when calibrating with either simulated load or material, you should first establish repeatability before making any adjustments to the scale. This can be done by repeating the calibration or material test twice without making an adjustment. The scale can be adjusted, once repeatability has been established.

Simulated load calibration

Simulated load calibration runs should be done periodically to test the scale for any changes that may affect its accuracy. Stability of current scale technology has come a long way in recent years. In the past, periodic simulated load calibrations were needed to adjust for drift in the load cells, scale electronics, or for changes to the conveyor itself. Advances in tempering techniques, strain gauge technology and digital scale integrators ensure that the scale remains very stable over long periods of time. However, routine simulated load calibration runs are still required to adjust for changes that occur to the conveyor. The frequency of these calibration runs is a function of conveyor stability and dynamic scale load. Routine calibration runs should be done in accordance with the manufacturer's guidelines, taking into account the conveyor stability and the accuracy required.

Material testing

After a conveyor belt scale is installed and the initial simulated load calibration has been completed, the scale should be material tested. Material testing is the process of transferring a material sample across the conveyor belt scale and comparing the totalised weight of the conveyor belt scale with a measurement of the same sample of material on a known accurate scale, most often a truck scale or a platform scale. Material testing is the most accurate method of calibration as it is done under real operating conditions. The material sample should be large enough to produce an appropriate resolution on the totaliser to achieve the desired accuracy. The size of the material sample can be calculated using the following formula:

Material test sample size = (1/required accuracy) x belt scale totaliser resolution

For example, a required accuracy of 0.5% means that the sample size must be large enough to produce a minimum of 200 counts on the conveyor belt scale totaliser. Therefore, if the totaliser on the belt scale system is incremented every 0.01 t, then the sample would have to be 2 t.

Best practice calibration

Simulated load calibration should be done periodically to verify the scale's accuracy. When the scale is calibrated, first establish the scales repeatability before making any adjustments, and then record the deviation from the previous calibration. It is also a good idea to record the belt speed and load cell outputs at the time of calibration so they can be compared to previous measurement should any issues arise.

Comply with the manufacturer's recommendations regarding how often a calibration run should be made. The time between calibration runs can be shortened if you identify accuracy issues. As a minimum, simulated load calibration runs should be done seasonally and any time maintenance is done on the conveyor.

A cement producer in the southern US initially established a periodic maintenance schedule to calibrate a newly installed belt scale weekly. For each calibration run, they recorded the deviation from the previous calibration run. By comparing the deviations between calibrations, they found these deviations were within acceptable limits over multiple calibration intervals. To reduce downtime for calibration, they decreased the frequency of the periodic calibration runs to once a month, and were still able to maintain the desired accuracy.

Maintenance

Scale maintenance

As discussed above, simulated load calibration should be done periodically. The scale should be visually inspected when preforming a routine calibration run, which involves ensuring that the rollers on the scale idler and the idlers around the scale can freely rotate. The scale should also be inspected for material build up that may restrict the movement of the weigh idler. Generally speaking, it is not necessary to remove all of the material that has built up on the scale and scale idler – and in some cases it can be advantageous to leave some material on the weigh bridge. In the harsh environment of a cement plant, material build up is likely to occur. However, it builds up to a certain point, and when the material angle reaches the angle of repose it does not increase any further. At that point, a zero calibration can be done to take the buildup into account. What is critical is that the material build up is not enough to restrict the movement of the weigh idler or the idlers in the scale area from rotating freely.

The scale inspection should also include inspecting the speed sensor. Shaft-mounted speed sensors should be inspected to verify that there is no slippage between the speed sensor shaft and the conveyor shaft. Trailing arm or return belt speed sensors should be inspected to verify that the speed sensor wheel does not manifest any excessive wear – and that it has good contact with the return side of the belt. Note that speed represents half of the calculation, therefore substantially influencing the repeatability and accuracy.

Conveyor maintenance

Routine conveyor maintenance and good housekeeping for conveyers that have a belt scale are critical to the operation of the weighing device. Improper belt tension and poor belt tracking will have a negative impact on the scale performance.

There are two common types of belt tensioners, gravity take-up systems and screw take-up systems. Conveyors longer than 36 m and equipped with a belt scale should use a gravity take-up system to prevent changes in belt tension caused by belt stretch from affecting the scale. Gravity take-up systems should be correctly weighted and operating perfectly. A properly tensioned belt should have about a 2% sag in the belt.

Belt tracking refers to the ability of a conveyor belt to stay centreed on the conveyor idlers. Inconsistent belt tracking can change the belt tension, alter how material lies on the belt and increase material spillage to the point where it restricts vertical displacement of the weigh idler. All of these can affect a conveyor belt scale's accuracy. Belt tracking should be consistent and ensure that the belt is centred on the carrying idlers.

To adjust belt tracking, the screw tensioners are used to adjust how square the tail pulley is to the belt line. Often, when correcting belt tracking, the screw tensioner on one side will be tightened; the belt is then monitored to see if it tracks down the centre of the belt line. If the belt moves too far to the other side of the conveyor, the other tensioner screw is tightened. This process is repeated several times until the belt tracks correctly. However, this can cause the belt to become overtightened. When adjusting belt tracking, always adjust the screw on one side, tightening it when the belt moves to that side and loosening it when it moves to the other side.

Maintenance precautions

When maintenance is carried out on the conveyor, care should be taken not to damage the scale. Sharp blows to the scale idler or welding near the conveyor scale can damage the load cells in the scale. When carrying out conveyor maintenance avoid striking the scale or weigh idler – and also avoid walking on the belt. If welding work has to be carried out on the conveyor, the ground cable of the welder should be placed between the scale and the point where the welding is being done. The wires to the load cells should also be disconnected from the integrator and connected together. These steps will significantly reduce the risk of damaging the load cells.

Best practice maintenance

When a conveyor has a belt scale, the conveyor must be properly and regularly maintained. Whenever maintenance is done to the conveyor, it is best to have someone that is trained on conveyor belt scale maintenance present so that any work that is done will not affect the performance of the scale.

A cement producer in the eastern US set up their work order processing system so that if a job is generated for any maintenance to a conveyor that has a belt scale, the system automatically notifies and involves personnel responsible for the scale.

Conclusion

Conveyor belt scales can give years of accurate service. Selecting an appropriate location and proper installation of a conveyor belt scale are key for a conveyor belt scale to provide accurate measurements. Maintenance is critical to keeping the scale operating properly for many years. While the scales will require routine calibration and good housekeeping, proper maintenance of the conveyor is critical.