PROCESS INSTRUMENTATION

Successful Application of Load Cells in an Industrial Environment

Accurate weight measurements are critical for inventory management, optimizing production, and quality control in any bulk manufacturing facility. Load cells are the heart of any modern weighing system, properly selecting and installing the load cells are the first step to ensuring many years of accurate measurement. This paper discusses common industrial weighing applications, the types of load cells, how to select the proper load cell, and how the load cell installation can affect the scales accuracy.

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Industrial uses of weigh measurements

The three most common uses for industrial scales are inventory control, process control, and custody transfer. Accurate inventory measurements allow proper production scheduling, proper ordering of raw materials, or the inventory measurement may be used for fiscal responsibility. Weigh measurement also allows accurate process control, reducing scrap or the need to reprocess material. Finally, in an industrial environment, weight measurement may be used for custody transfer, a method to determine the value of bulk goods to properly bill customers.

Industrial weighing applications

Industrial weighing applications can be classified in three categories, non-automatic scales, automatic scales, and continuous scales. Although each type of application may have specific requirements on their installation and maintenance, the basic requirements for load cell use will remain the same.

Non-automatic scales required an operator's intervention during the weighing process. This intervention could be as simple as reading the weigh measurement. Some examples of non-automatic scales are platform scales and bin weighing systems. Platform scales use a platform mounted to one or more load cells. An object is placed on the platform and the weight measurement is taken. Bin weighing systems use load cells under a tank, hopper, or small bin. The weight of the vessel is calibrated out and the amount of product in the vessel can be determined by the weight measurement.

Automatic scales do not require an operator's intervention during the weighing process. The weighing process is carried out following a predetermined process. Examples of automatic scale include filling scales, batching scales, and checkweighers. Filling scales measure material as it is put in a container. The container is moved onto a platform scale and the weight of the container is measured as material is put into the container. When the target weight is reached, the filling process is stopped by the scale electronics, the container is moved off the platform, and a new container is moved onto the scale. The entire process is carried out in an automated system. Batching scales use load cells on a mixing tank. The weighing system determines when the correct amount of material has been moved into the mixing tank and turns the filling process off. This is repeated with each component of the batch. With both filling and batching scales, the goal is to reach the setpoint as quickly as possible and stop the material flow as close to the setpoint as possible. To do this, these types of weighing systems will have functionally built in that will monitor the amount of material that is put into the vessel, as the setpoint is approached, the flow rate will be switched to a slower fill stream so that the fill can be turned off with very little difference between the desired setpoint and the amount of material delivered. Checkweighing systems measure the weight of individual items as they are transferred across a belt or roller conveyor. Checkweighing systems with belt conveyors use a short conveyor that is designed specifically for the Checkweighing system. There is a section of the carrying side of the belt that is supported by a platform. The platform is mounted to one or more load cells. Checkweighing systems on roller conveyors use a section of the roller conveyor that is supported by load cells. In both cases, the scale will use a peak measurement or a photoelectric sensor to determine when the item being weighed, is completely on the weighing portion of the conveyor.

Continuous scales measure the weight of bulk material as it is transferred in a continuous process. These scales typically have two outputs, the instantaneous rate, and an accumulated total. These types of scales include belt scales, solids flow meters, and loss in weight feeders.

Belt scales measure bulk material as it is transferred on a belt conveyor. Belt scales use load cells placed under one or more of the idlers that support the belt, a speed measurement is also made, these measurements are used to determine the amount of material being transferred across the conveyor. Solids flow meters measure dry powder or granular material that is flowing through a pipe. One type of solids flow meter directs the material flow across a plate and the force caused by the material striking the plate is measured to determine the amount of material flowing through the flow meter. Loss in weight feeders are designed to control the feed rate of a dry material in a process. Loss in weight feeders are most often used to control the flow rate of dry solids as they are blended in a continuous process. They use a small hopper with a screw conveyor discharge. The hopper and screw conveyor are mounted on load cells. As the screw conveyor draws material out of the hopper, the load cells measure the rate at which the material is removed. A control loop controls the rate of discharge by increases and decreases the speed of the screw conveyor.

Theory of load cells

Regardless of the type of application, the load cell is a critical component of most modern weighing systems. The most common type of load cells, are strain gauge load cells which use a strain gauge, bonded to a load cell body to measure force. Strain gauges use the principal that resistance is a function of the cross-sectional area and length of the conductor. It can be thought of like this, if a piece of wire is stretched, the diameter of the wire will decrease, and the length of the wire will increase. In a linear relationship, the resistance of the wire will go up. This change in resistance is very small so to increase this effect, a strain gauge, as shown in Figure 1, will use a pad with the conductor arranged so that as the pad is stretched, the conductor will stretch in multiple locations.

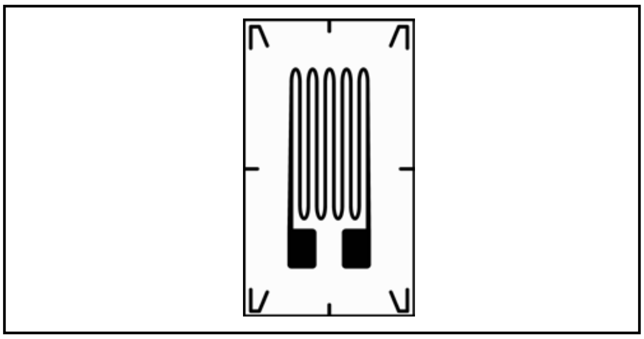

Figure 1- Typical strain gauge

The load cell body is designed to deflect a slight amount, less than 1mm, in specific locations as a force is applied. The load cell shown in Figure 2 is designed to deflect in locations R1, R2, R3, and R4 as force is applied. A strain gauge is bonded to the load cell body in each of these locations. As a force is applied, strain gauges in positions R1and R4 are stretched and the strain gauges in positions R2 and R3 are compressed.

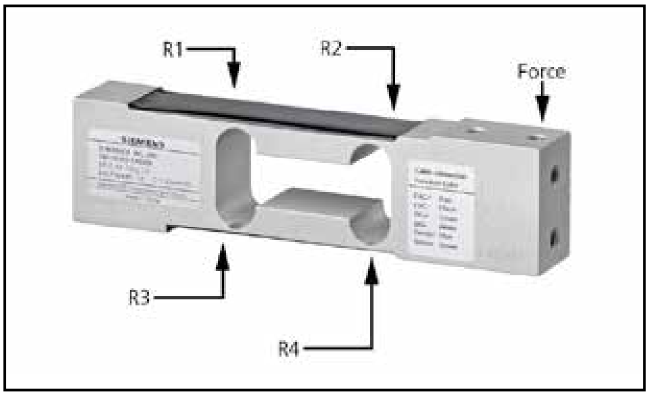

Figure 2 – Typical single point load cell

The strain gauges are configured in a Wheatstone bridge with the strain gauges in compression on opposite legs of the bridge and the strain gauges in tension on opposite legs of the bridge. A DC voltage is applied to the Wheatstone bridge and the it will output a millivolt signal that is proportional to the load applied to the load cell. The output of a load cell under full load is normally specified as the load cell's characteristic value, this will be in millivolts of output per volt of excitation (mv/V). A common load cell characteristic value is 2mv/V, and a typical load cell excitation voltage is 10 volts, so the output of the load cell under full load will be 2mv X 10 V or 20mv.

Selecting the Proper Load Cell

When selecting the proper load cell, several factors should be considered. Things like responses time, creep, hysteresis, and non-linearity can affect the accuracy of the weighing system. The importance of these specifications depends on the application. An example of where response time would be an important consideration is high speed applications like filling machines and checkweighers, but creep may not be an issue in these applications. Conversely, speed of response would not usually be an issue on a bin weighing system used for inventory management, but creep could be. Consult your load cell supplier to determine which of these factors are most important in your application.

There are 4 general types of load cells, compression load cells, S-type load cells, beam type load cells, and single point load cells. Selecting the proper load cell type and capacity can also affect the performance of the weighing system. Table 1 shows examples of each type load cell. Compression load cells are vertical cylinders with a load bearing point in the center of the top of the cylinder.

Compression load cells are capable of handling very high loads, in some cases up to 500 tons per load cell. Because of their high capacity, they are often used for bin weighing systems or vehicle scales. S-type load cells have an "S" shaped frame. They are most accurate when used in tension, so they are often used in hanging type scales. S-type load cells are mounted or suspended from the top of the load cell and the load is attached the bottom of the load cell. Beam load cells can be cuboid or horizontal cylinders, in most cases they are rigidly mounted on one end and the load is applied to the other end. There are also double ended beam load cells that are a horizontal cylinder or cuboid that is supported on both ends and the load is applied to the center of the beam. Single ended beam load cells typically have capacities up to around 35 tons. They can be used in such applications as smaller bin weighing systems or larger platform scales. Single point load cells, like beam load cells, are cuboid shaped and are rigidly mounted on one end.

Single point load cells are designed for small platform scales, usually up to about 36 inches square. Single point load cells are normally used in weighing systems where only one load cell is needed to support the platform and would typically not be used in scale systems where 3 or more load cells are used in a single weighing application.

Each type of load cell will have a variety of different load cell capacities. The live load, deadload, safety factor, and the number of support points should be used to determine the proper load cell capacity. Live load is the temporary weight that will be applied to the load cell, this will be what is being weighed. Dead load is any permanent weight that will be applied to the load cells. This would be anything to support the item or items that are being weighed. For example, on a platform scale, the dead load would be the weight of the top plate of the scale, known as the load carrier, and any hardware required to attach the plate to the load cell. The live load and dead load are added together to determine the total load. A safety factor in a weighing system, usually expressed in a percent of total load, is additional load cell capacity that may be required in the application for environmental influences. For example, if a bin weighing system is located in an area that may have wind loading or forces from seismic activity an appropriate safety factor should be applied to allow for these forces. There is sometimes a tendency to significantly oversize the load cell to account for these external influences but that can also have a negative impact on the scale's accuracy. If too large of a safety factor is used, the resolution of the weighing system may not allow accurate measurements. To be certain the load cells are properly sized for your application, consult your load cell supplier to determine the proper safety factor for your application. After determining the proper safety factor, the capacity of the load cell can be calculated by dividing the total load by the number of support points and multiplying it by the safety factor plus 1 and the next larger size load cell is selected. For example, if the total load on a bin weighing system is 24T, the bin has 3 support legs, and requires a safety factor of 20%, the minimum load cell capacity would be calculated as 24/3 X (1+0.2) or 9.6T. If a 9.6T load cell is not available, the next larger size load cell would be used, most load cell manufactures have a 10T load cell in their portfolio.

Load Bearing Systems

A weight measuring system will bear the weight of the load in specific locations called bearing points. Load cells are installed at each bearing point. The most common bearing systems will have 1, 3, or 4 bearing points. The load should be centered on the load cell and applied straight down without any rotational or leverage forces. Any forces other than a direct force downward or any off-center loading can cause errors in the weighing system.

Compression Load Cell	S-Type Load Cell	Beam Type Load Cell	Single Point Load Cell
			

Table 1

To allow the load to be applied equally across each load cell, all bearing points should be level and rigid enough to support the load without deflection. If the load cell mounting base is not level the load will not be applied straight down. Similarly, if the mounting base for the load cell deflects under the load, the load will no longer be applied straight down, causing errors in the weighing system and could cause structural damage to the load carrier.

All the bearing points should also be at the same level. On weighing systems with 4 or more bearing points, if one bearing point is higher than others, the load cell under the higher bearing point will carry more of the load. To be certain all the bearing points are on the same level, after the load cells have been installed, the output of each load cell should be checked before the live load is applied. The output of each load cell should be within 20% of the others. If one or more of the load cells has a greater difference, shim plates should be used to level the load cells until the output of the load cells are all within 20% of each other.

Installation requirements

As discussed in the Theory of Operation, load cells must deflect slightly to operate properly. Anything that restricts the vertical movement of the load carrier will cause errors in the weighing system. Whether it is a conveyor belt scale or a bin weighing system one of the more common sources of error is the restriction of the vertical movement.

To allow the proper vertical displacement, anything connected to the load carrier must be able to flex. For example, on a bin weighing system, any fill pipes, vents, discharge piping should allow the bin to move down slightly. Any restriction in downward movement will cause errors in the weighing system. This can be done using soft couplings, in some cases, "C" bends in the pipe as shown in Figure 3 can allow for this deflection.

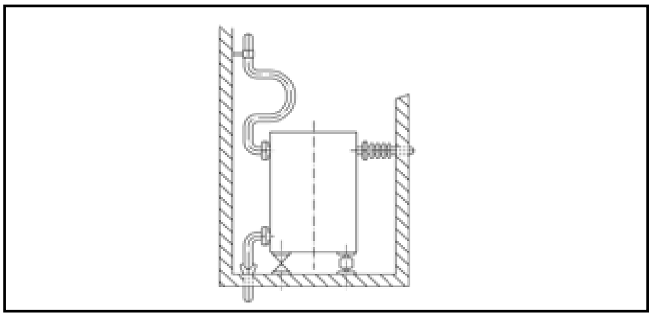

Figure 3

Additionally, scales using beam or compression load cells require the load carrier to "float" on the top of the load cells. Because the load carrier is "floating" on top of the load cells, the load carrier must be protected from slipping off the load cells. Stay rods, as shown in Figure 4, are typically used to prevent lateral movement of the load carrier. A Structural Engineer should determine the proper size and placement of stay rods for your application.

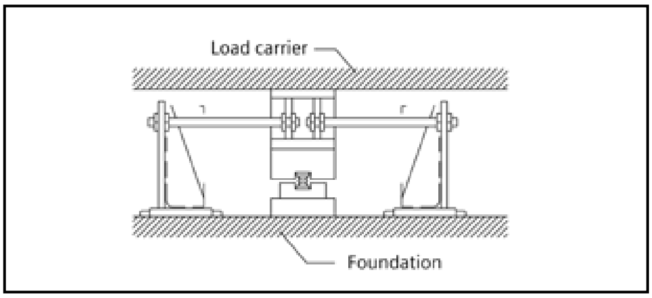

Figure 4

In addition to stay rods, liftoff protection should be provided to prevent the load carrier from lifting off the load cell. It should be designed so the load carrier cannot be lifted more than 1 mm above the load cells. This can be done with a piece of structural steel firmly mounted to the foundation and fixed 1 mm above the load carrier. On bin weighing systems there is often an "I" beam between each leg of the bin, if this is the case, the structural steel can be fixed between the horizontal sections of the I beam as shown in Figure 5.

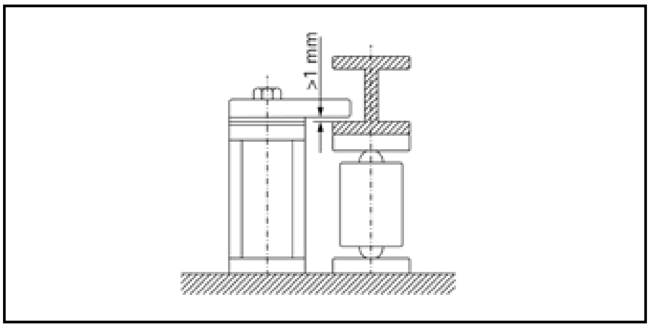

Figure 5

Conclusion

Load cell weighing systems are very common in industry. Proper equipment selection and installation is will enable the weighing system to provide very accurate weight measurements in a wide range of conditions. A proper installation requires taking steps to ensure the load is correctly applied to the load cell and the load cells vertical deflection is not restricted.

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