Industrial Electronics — 4

Electronic weighing

by Richard Graham

It is a remarkable thought that the kind of measurement which must have been one of the first that man ever made is the one which has resisted the attentions of electronic engineers the longest. It is probably not much more important to weigh things accurately today than it was when the brontosaurus steaks had to be shared out equally, but it is now considered to be insufficient to read the weight from a weighing machine; the result of the measurement must be printed, transmitted, used in computation or used to control a blending process.

The call for electronic weighing is therefore not primarily motivated by its potential accuracy, but rather by its direct provision of an electrical signal — analogue or digital — which can be used to fulfil the ancillary functions of weighing. This is, perhaps, just as well, because the achievement of accuracy in an electronic weighing system is a difficult and expensive business; only in the last few years have electronic machines reached a performance comparable in accuracy to that of the mechanical type of scale.

Hybrid weighers

The first attempts at deriving an electrical output from a weighing process were, as seen in Fig. 1, hybrid in nature. The spindle of an ordinary dial scale was fitted with a rotary displacement transducer, which produced either analogue or digital signals corresponding to the position of the scale pointer. The transducer could be either a photocell-scanned diffraction grating or a refined type of slide-wire potentiometer, the former possessing the considerable advantage of friction-free operation and direct digital output.

These systems combine the advantages (and the disadvantages) of electrical and mechanical operation, and the feeling was that the benefits of electronics were not being properly exploited. For instance, the construction of a mechanical weighbridge consists of unbelievably large lumps of steel, supported on knife-edge bearings. When new, the whole edifice is capable of weighing extremely accurately and with excellent repeatability. Unfortunately, this state of affairs does not last indefinitely; knife edges and the dial mechanism wear and the pointer begins to "stick", maintenance is therefore required. Moreover, since the platform of the weighbridge must usually be flush with the ground, a sizeable hole in the ground is needed to house the lever mechanism.

On the other hand, a purely electronic weighbridge consists of the platform, a number of load cells, and a box of instrumentation, as shown in Fig. 2. Admittedly, the pit remains, but can be considerably shallower and, in some cases, can be dispensed with altogether, a ramp being used instead. The output of the instrumentation can be either analogue or digital, and no "sticking" will be observable.

Electronic weighers

The device which has made possible the present state of electronic weighing is the strain gauge used in a load cell. Other types of load cell have been proposed, but strain-gauge cells presently reign supreme. In essence, the device is simple, but it has taken at least twenty years to reach the current state of parity with mechanical weighers, and even now there are problems to be solved. After many years of development, the strain gauge has now stabilized into several forms. It is yet another illustration of a simple idea which is ferociously difficult to implement, and its development was retarded by the fact that most of the early workers in the field spent a lot of time industriously measuring and recording the wrong parameters, neglecting vital information.

If one considers a piece of metallic material of length L, cross-sectional area A and specific resistance p, its resistance end-to-end is expressed as pL/A. If it is deformed, becoming shorter and fatter, its resistance therefore decreases, deformation by stretching giving an increase in resistance. To apply this effect to a weigh-

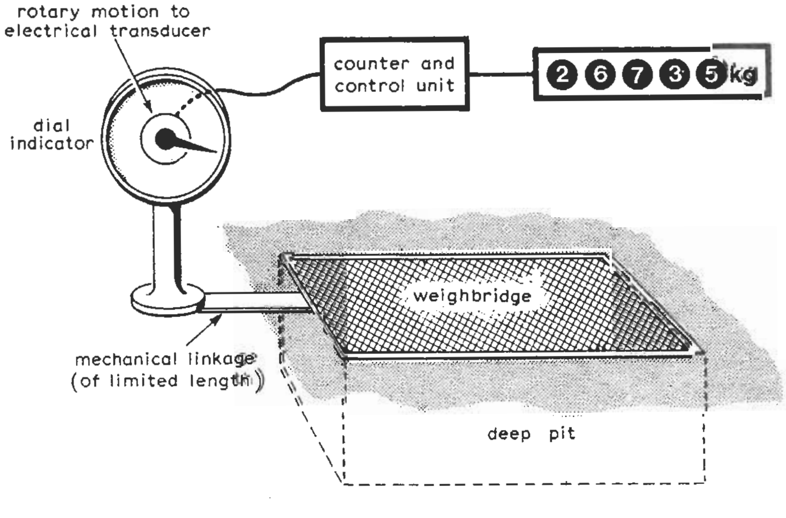

Fig. 1. A hybrid mechanical/electrical weigher.

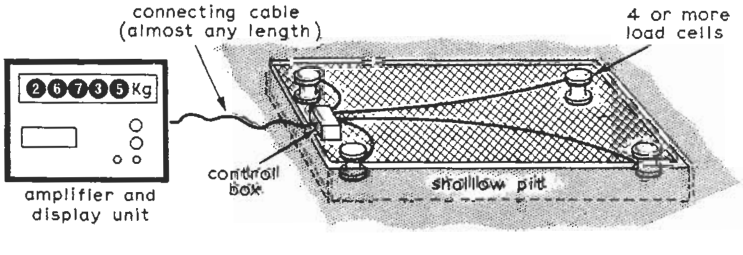

Fig. 2. Electronic weighing system.

ing system, the strain gauge is used in conjunction with a deforming spring structure, the load cell. Fig. 3 shows one form of load cell, the "active" part being the narrow centre section. As a load is applied to the button at the top, the neck becomes very slightly deformed or squashed — by a matter of a few hundredths of a centimetre decrease in height. This deformation is accurately proportional to the applied load until the elastic limit is reached, and is measured by the strain gauges bonded to the neck. The gauges, in the simplest configuration, are arranged in the form of a wheatstone bridge and the output signal is around 2mV per input volt. The signal is amplified, usually digitized and displayed. Many companies use a dial display, but this always seems to be a throwback in much the same way as cars having their engines at the front because that is where the horses used to be.

That is a typical electronic weigher in principle. As may be suspected, there is a lot more to it than that. For instance, a load cell would, if precautions were not taken, do a reasonably good job of being a thermometer; it could also suffer from the bonding of the gauges being imperfectly done and the ingress of moisture would not help. The metal of the billet must be of the correct type and the proper application of the load to the cell is a matter of vital importance.

For normal, mid-range temperature operation, the foil type of gauge is used. Fig. 4 shows the general arrangement of such a gauge. The gauges are manufactured by a process similar to that by which printed circuits are made. An extremely thin (about 5 microns) strip of constantan, or whatever metal is chosen, is coated on one side with synthetic resin and on the other side with a photo-sensitive resist. The resist is exposed to the required pattern through a negative, the exposed parts hardened and the rest removed. The remaining pattern can be etched away chemically, leaving the final gauge on a synthetic resin carrier, which is then bonded to the load cell billet and leads are welded or soldered to the pads. Resistance wire gauges are used for higher temperatures and many different patterns of gauge are used for other applications.

Two-component bonding materials are often used, consisting of a monomer and hardener, polymerization taking place on mixing and setting occurring in a short time with heat applied. The important features of a bonding agent are its life and creep properties, sensitivity to moisture and resistance to radiation. (Creep is the effect observed when a suddenly-applied load is reflected in a gradual approach to the final resistance value of the gauge.)

It is obvious that at least three load cells must be used to form a stable support for the weighing platform, and it is usual to use a minimum of four and sometimes eight, depending on the size of the platform. The way the cells are connected together to give a signal output determines the sensitivity of the system, and also, to some extent, the type of supply used.

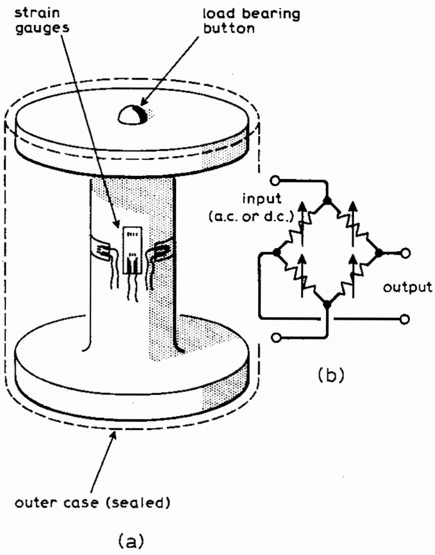

Fig. 3. A typical load cell.

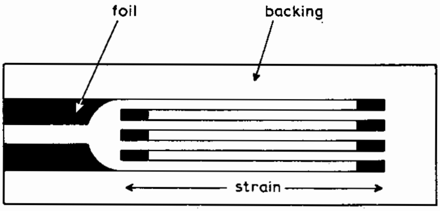

Fig. 4. One type of etched-foil strain gauge.

If cell outputs are connected in series, with separate drive inputs, then the combined output is that of one cell. The output impedance is high and three supplies are required. On the other hand, if the outputs are in parallel, the signal is 1/n that of one cell, where n is the number of cells. The output impedance is low and only one supply is needed. It is common practice to use a series-parallel combination of cells, giving reasonably low impedance, adequate sensitivity and not too much trouble with power supplies.

The type of cell described is one of several different styles: they are also made in the form of rings and horizontal beams, depending on the range of weights to be measured and on the method of applying the compressive or tensile force to the transducer. Accuracies are usually grouped into two classes — general-purpose and precision. A precision cell, used in weighbridges which must satisfy official requirements, is capable of calibration error, non-linearity, hysteresis, and creep of around 0.05% of full output, while the general-purpose variety will give calibration errors and non-linearity of 0.1 to 0.25% full rated output. Temperature effects vary from 0.001% to 0.005% of rated output.

That, then, is a very brief description of the basic weighing element. There remains its application to the business of weighing, the ancillary instrumentation and the use of complete systems in industry. I will try to cover as much of this as possible in the next article.