Group Four Transducers Inc

What Puts the 'Quality' Into High Quality Strain Gage Load Cells?

Strain Gage Load Cells are manufactured all over the world; some with very high quality and others with marginal to poor quality. Load cell users should be aware of what goes into manufacturing a quality load cell. This paper will attempt to do that in "lay terms" in order to assist the potential load cell user in making the best load cell choice for his application.

The Basic Load Cell:

All load cells consist of the following main components:

1. The spring element which converts the applied force or mass to a measurable strain.
2. The strain gage, usually four, which converts the measured strain to a measureable voltage.
3. Temperature compensation components which reduce the effects of temperature on the load cell's zero and span.
4. Components for the reduction of adverse load effects.
5. Printed circuit boards or flex circuits to mount all of the calibration and temperature compensation components. A cable to connect the load cell to junction boxes or display instrumentation.
6. Load introduction means to apply the force or mass to the load cell.
7. Sealing means to prevent the entry of moisture or chemicals into the load cell.
8. The quality of a load cell is dependent upon how each of the above parts of the load cell is treated in the initial design phase and in the subsequent manufacture and testing of the load cell.

The Spring Element:

Over the years the industry has settled on a few steel and aluminum alloys for the production of quality load cells: 4340 alloy steel, 17-4 PH stainless steel and 2024 T351 and 2024 T3 aluminum.

Certainly other materials and alloys of lower cost can be employed but usually with a sacrifice in performance such as higher hysteresis, higher creep and change in creep with temperature, poorer corrosion resistance in certain less expensive stainless steel alloys, and less reliable overload performance when materials with lower mechanical properties are used.

Alloy steel and stainless steel spring elements must be carefully heat treated to ensure the highest in mechanical properties such as ultimate tensile strength, yield strength and toughness. Precipitation hardening stainless steels such as 17-4 PH should follow rather meticulous heat treating and post heat treating processes to ensure the best in hysteresis. This is a more expensive process and one that is not followed in lower quality load cells.

The alloy of choice for aluminum load cells (2024 T351) has excellent mechanical properties which can be compromised in the manufacturing process if too many repeat gage application cycles at elevated temperatures are performed which reduce the mechanical properties of the alloy. Avoiding these "regaging cycles" is expensive but it leads to higher load cell quality.

Given that proper material and heat treating process choices have been made the actual spring element or sensing element design becomes crucial to good performance.

Rapid changes in cross sections which cause stress concentrations should be avoided. Opportunities for large reflected stresses at the loaded and mounted ends being sensed by the strain gages should be avoided because these reflected stresses generally change in unexpected ways sacrificing load cell stability and repeatability.

A frequently overlooked design criterion in sending element design is geometric symmetry. If one or more of the four strain gages sense different absolute strain values because of asymmetry in design it is possible that electrical bridge nonlinearities will result and repeatability performance may suffer as a result of less cancellation of reflected stresses.

The Strain Gage:

Invented independently and concurrently by Ruge and Simmons 72 years ago, the strain gage remains one of the most accurate sensors available for performing mechanical measurements such as force, mass, pressure, tongue and displacement.

Unfortunately, the strain gage's apparent simplicity has encouraged worldwide manufacture resulting in a broad range of strain gage quality.

Poorly manufactured strain gages exhibit excessive creep and a high change in creep with temperature, poor nonlinearity and hysteresis and inferior "solderability".

Strain gages are made with and without a thin polymer sheet covering the strain gage grid. The gage types are called "open face" and encapsulated gages, respectively. A load cell made with encapsulated strain gages will be easier to protect from debilitating moisture entry than load cells made with open face strain gages. Load cells made with encapsulated strain gages may perform better in high humidity and "wash down" environments.

Most strain gage manufacturers offer strain gages with creep codes which allow the load cell manufacturer to choose strain gages which have creep factors equal and opposite to the creep in the sensing element, resulting in acceptably low net creep. This "one time adjustment," however, may be satisfactory at only room temperature for some strain gages exhibit creep which changes with temperature. A high quality strain gage will exhibit very little change in creep with temperature.

Unless the load cell manufacturer makes his own strain gages the strain gage is a relatively expensive item and there are at least four of them required. The smaller the grid size the lower is the cost because of certain characteristics of the strain gage fabrication process. As result, load cell manufacturers who must purchase their strain gages are encouraged for economic reasons to use smaller grid sizes with a sacrifice in performance such as higher creep and higher change in creep with temperature and possible temperature instability due to higher power dissipation per unit strain gage grid area. Higher quality load cells employ encapsulated strain gages and larger strain gage grid sizes...

Temperature Compensation Components:

Load cells have two temperature errors: temperature effect on zero balance (TCZ) and temperature effect on span (TCS)...

Most load cell manufacturers compensate the TCZ error inside the strain gage bridge wiring which is complicated and fraught with difficulties of preventing the unprotected compensation elements from shorting out to the element.

A few manufacturers (including G4 and 3S) use a compensation method which is performed outside the bridge using simple metal film resistors, avoiding the above "mechanical" problems. This approach contributes to higher quality.

TCS errors are compensated with temperature sensitive resistors in series with the excitation terminals of the strain gage bridge. These resistors are generally in the form of strain gage grids wherein the grid material is temperature sensitive Nickel of Balco.

Some manufactures take short cuts and install the TCS compensation components in only one side of the bridge. This causes the voltage on both signal leads to increase and decrease with temperature which can cause "common mode" signal errors in the display instrumentation. This practice is not used in high quality load cells.

Printed Circuit Boards and Flex Circuits:

PCB's and flex circuits are the best means for accommodating the somewhat complicated wiring of a load cell and are found in higher quality load cells. Some lower quality load cells use point to point wiring and a few solder terminals here and there, suffering, as a result, shorts to element and, fatigued wiring due to the vibration of unsupported lead wires.

Higher quality load cells use PCB's and flex circuits with "solder mask" which helps to protect the wiring from the effects of moisture induced lower insulation resistance.

The Cable:

The load cell cable is frequently overlooked as to the importance of providing good strain relief and preventing the entrance of moisture into the load cell by capillary action through the conductors.

A high quality load cell will have good strain relief to avoid its being ripped out through mishandling. It will include a "water block" within the cable to prevent moisture from entering the cable entry area through capillary action.

Load Introduction Means:

A load cell is no better than its load introduction means and this is too frequently overlooked in favor of the "threaded load introduction" which, while simple, is subject to the introduction of off center loads, side loads and torsional loads because of the inflexibility of this type of load introduction.

High quality load cells will employ blind hole load introduction and rocker pins with convex loading surfaces. Alternatively, a fixed convex loading pin can be used with somewhat less but quite good performance. Both forms reduce off center load application which is the goal in good load introduction.

Rocker column load cells, by their nature, have inherently good load introduction. They virtually eliminate all side loads because they "rock"... The "off set load error" (when tilted) is reduced through compensation in the higher quality rocker column load cells as already described.

Threaded load introduction is virtually a must in "S:" beam load cells but the negatives in that form of load introduction can be eliminated with clevices and monoball joints. In compression applications a convex spherical load button can be used.

Sealing:

Quality load cell manufacturers spend a lot of time on the design and evaluation of their sealing techniques. Sealing is not easy. Moisture will penetrate every polymeric seal, in time. But if the average of a cyclic moisture environment is relatively low the polymerically sealed load cell will survive.

It is very difficult to evaluate the sealing of a load cell through visual observation. Some of the nicest looking coatings provide very little moisture protection. And the manufacturer won't divulge his sealing materials because they are "proprietary". So, only experience and reliable hearsay will help in this case.

Some load cells are hermetically sealed at the strain gage cavity with thin walled sleeves and cups but no hermetic sealing is provided at the cable entry. This offers questionable improvement over load cells sealed with polymers for moisture will enter the load cell by capillary action through the cable.

For "true" hermetic sealing the load cell should be hermetically sealed at the strain gage cavity and at the cable entry using a glass to metal sealing header that is soldered or welded in place. In addition, the cable entry cavity outside the header should be filled with a polymer that not only fills the cavity but creeps into the cable for a distance of about six inches by capillary action thereby providing a moisture block where the cable enters the load cell.

In addition to all of the above it is essential that very good strain relief is provided at the cable entry by means of compression "stuffing glands" which hold the cable firmly in place, preventing the conductors within the potting compound from moving when the external cable is moved for whatever reason.

Concluding Remarks:

It should be clear from this rather lengthy discussion of what factors contribute to quality in a load cell that this seemingly simple force measuring device is not so simple after all.

Each of the eight areas discussed above require careful and creative attention to detail in order to provide a quality load cell. Failure to do so in one or more of these areas results in a lower quality load cell.

Anyone faced with the selection of a high quality load cell would do themselves well to investigate each of the above eight areas in each potential load cell choice to ensure that they make the best choice for their application and budget.

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