Journal of Basic and Applied Engineering Research
Print ISSN: 2350-0077; Online ISSN: 2350-0255; Volume 2, Number 9; April-June, 2015 pp. 706-709

http://www.krishisanskriti.org/jbaer.html

Design and Fabrication of Micro Load Sensor

J. Raghu Raj[1], VVLN. Sravanthi[2] and V. Diwakar Reddy[3]

[1]PG Scholar, Dept. of Mechanical Engg. SVU College of Engineering, Tirupathi
[2]Dept. of Mechanical Engg. SVU College of Engineering, Tirupathi
E-mail: [1]raghuraj349@gmail.com, [2]vdrsvuce@gmail.com

Abstract—*Load cells are transducers used to measure force or weight. Despite the fact that there is a wide variety of load cells, most of these transducers that are used in the weighing industry are based on strain gauges. Today, except for certain laboratories where precision mechanical balances are still used, which are also called strain gauge load cells dominate the weighing industry. Still marketed products are standardized based on the requirement, size, capacity, Quantity etc. An attempt is made to fabricate micro load sensors. These loads can be used either for measuring the quantity of load applied or sensing the overloads in the machinery or equipment etc. in order to predict the hazards.*

In this proposal, a disc-spring based load cell with strain gauges was suitably assembled to the mechanical structure. This system is used to measure the resistance of the mechanical structure to compressive forces applied normally to the seats being tested and also one application towards the load cell was included with suitable calibration, which is a performance test for judging the quality of the system.

1. INTRODUCTION

The project involves designing and fabricating a Micro load cell. Basically the entire work could be divided into four stages, which are Introduction, concept review and development, designing and fabrication. This chapter involves the introduction of micro load cell and its components. The components involved are Belleville spring, Strain gauge, and micro strain indicator.

Before strain gauge-based load cells became the method of choice for industrial weighing applications, mechanical lever scales were widely used. Mechanical scales can weigh everything from pills to railroad cars and can do so accurately and reliably if they are properly calibrated and maintained. The method of operation can involve either the use of a weight balancing mechanism or the detection of the force developed by mechanical levers. The earliest, pre-strain gauge force sensors included hydraulic and pneumatic designs.

1.1 Belleville spring

A Belleville Spring is a conical shaped disc that will deflect at a given spring rate when subjected to an axial load. This rate is usually very high relative to a coil spring, which makes a Belleville an excellent candidate where large loads must be delivered through a short movement. Some applications where Belleville springs are commonly found are clutch and brake mechanisms in heavy equipment, punch and die sets, bearing assemblies, switchgear, and anywhere bolt pre-load must be maintained over time.

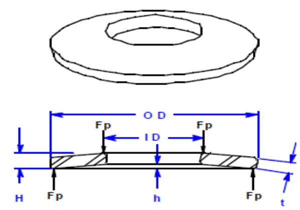

Fig. 1.8: A section of a Belleville Spring showing load Fp applied at the upper-inside and lower outside corners

A Belleville washer, also known as a coned disc spring, conical spring washer, disc spring, Belleville spring or cupped spring washer, is a type of spring shaped like a washer. It has a frusto conical shape which gives the washer a spring characteristic. The Belleville name comes from the inventor **Julian F. Belleville**. Belleville washers are typically used as springs, or to apply a pre-load of flexible quality to a bolted joint or bearing. Some properties of Belleville washers include high fatigue life, better use of space, low creep tendency, high load capacity with a small spring deflection and possibility for high hysteresis (damping) by stacking several Belleville washers on top of each other in the same direction. They may also be used as locking devices, but only in applications with low dynamic loads, such as down-tube shifters for bicycles. Belleville washers are seen on Formula One cars, as they provide extremely detailed tuning ability Belleville washers have been used as return springs in artillery pieces

2. LITERATURE REVIEW

This work reviews in detail the literature for a better understanding of the problem discussed in this area.

Liwei Lin, Albert P. Pisano, and Roger T. Howe, A Micro Strain Gauge with Mechanical Amplifier.

A passive micro strain gauge with a mechanical amplifier has been designed, analyzed, and tested. The mechanical amplifier provides a high gain such that residual strain in thin films can be directly measured under an optical microscope. This strain gauge can be in situ fabricated with active micro sensors or actuators for monitoring residual strain effects, and both tensile and compressive residual strains can be measured via the strain gauge. It is shown that a very fine resolution of 0.001% strain readouts can be achieved for a micro strain gauge with a 500- m-long indicator beam. Beam theories have been used to analyze the strain gauge with a mechanical amplifier, and the results were verified by a finite-element analysis. Experimental measurements of both polysilicon and silicon-riched silicon-nitride thin films fabricated by surface micromachining processes are presented. Journal of micro electromechanical systems, vol.6, no. 4.

A Torrents1, K Azgin1, S W Godfrey1, E S Topalli2, T Akin2 and L Valdevit1 MEMS resonant load cells for micro-mechanical test frames: feasibility study and optimal design This paper presents the design, optimization and manufacturing of a novel micro-fabricated load cell based on a double-ended tuning fork. The device geometry and operating voltages are optimized for maximum force resolution and range, subject to a number of manufacturing and electromechanical constraints. All optimizations are enabled by analytical modeling (verified by selected finite elements analyses) coupled with an efficient C++ code based on the particle swarm optimization algorithm. This assessment indicates that force resolutions of ∼0.5–10 nN are feasible in vacuum (∼1–50 mTorr), with force ranges as large as 1N. Importantly, the optimal design for vacuum operation is independent of the desired range, ensuring versatility. Experimental verifications on a sub-optimal device fabricated using silicon-on-glass technology demonstrate a resolution of ∼23 nN at a vacuum level of ∼50 mTorr. The device demonstrated in this article will be integrated in a hybrid micro-mechanical test frame for unprecedented combinations of force resolution and range, displacement resolution and range, optical (or SEM) access to the sample, versatility and cost.

2.1 OBJECTIVES OF THE PRESENT WORK

The objectives of the present work are:

- Designing the Belleville spring, which is an alloy of chrome vanadium steel and selecting suitable strain gauge and bonding method, then we will fabricate the desired micro load cell.
- We need to test this cell on universal testing machine for getting the maximum compression loading capacity and to Study the effects of deflection
- To show the variation of response practically and theoretically
- Conducting experimentation on any of the compressive loading machine (for example drilling machine)
- Most of the researchers used different materials and adopted different techniques to get desired outputs. In the present case, the effect of strain or deflection is studied with the help electrical resistance strain gauge load cell. the model picture of the load cell is as shown in below figure.

3. METHODOLOGY

Load cells are used in industry for weighing measurement. Basically a load cell is an elastic element to which an appropriate type of strain sensor is bounded. The application of a force to the elastic element cause a deformation sensed by the strain sensor providing an electrical output proportional to the applied force. These are the most commonly used load cells in many of the engineering and industrial applications.

In this chapter we are describing the designing idea of the elastic element theoretically by studying one specific problem and in the next chapter we can conduct an experiment which stands as practical approach to problem. The present work is proposed a novel structure designed for less space occupation and low cost compressive force sensing.

3.1 Designing idea

In this section we may state about the elastic member used in the load cell i.e. spring element. Here we are employing spring element having the shape of spherical dome which is generally called as Belleville spring. A Belleville Spring is a conical shaped disc that will deflect at a given spring rate when subjected to an axial load, which is made up of chromium-vanadium steel. This rate is usually very high relative to a coil spring, which makes a Belleville an excellent candidate where large loads must be delivered through a short movement.

Chromium-vanadium steel refers to steel alloys incorporating carbon, manganese, phosphorus, sulphur, silicon, chromium, and vanadium. Some forms can be used as high speed steel. Chromium and vanadium both make the steel more hardenable. Chromium also helps resist abrasion, oxidation, and corrosion. Chromium and carbon can both improve elasticity. We may show the chemical composition of chromium-vanadium steel alloy as follows

Chromium-vanadium is the most popular alloy steel for springs that are required to withstand a large number of operating cycles. It is medium carbon steel with chromium and

vanadium added to increase its hardness and tensile strength. Springs can be used at extremely high stresses in applications where they will also be subject to extreme shock and impact loading. For springs of high endurance, the alloy is usually used at a hardness of Rockwell C44-49. Where extreme stresses and short life are expected, the hardness is increased to Rockwell C50-53. In sizes .375” and under, chromium-vanadium alloy springs have no higher endurance limits than plain carbon steels of valve spring quality.

3.2 Design Considerations

The following criteria are generally applicable to all load cell spring elements. No interpretation should be made of the order in which they are presented, since the relative importance given to any of them depends upon the type and purpose of the particular transducer involved. Moreover, they are not independent of one another, but have numerous interactions. Good transducer design requires judicious, knowledgeable tradeoffs and compromises among these criteria.

- **Natural frequency:** Ordinarily, the natural frequency of the spring element should be as high as it can be made consistent with the specified sensitivity and other operating requirements for the load cell. This normally calls for a rigid, low-compliance design, without unnecessary mass.
- **Appropriate strain level in the gauge area at rated load:** At an early stage in the spring element design it is necessary to establish the element proportions so that a predetermined strain level will be developed in the gauge area when the unit is subjected to rated load. Based upon the combination of several different constraints (linearity of spring material response, fatigue life of strain gauges, instrument compatibility, etc.), the level is frequently set in the range from 1000 to 1700 micro strain. With a four-gauge fully active bridge circuit, 1500 micro strain will produce a nominal output signal of 3 mV/V of bridge excitation, based upon a gauge factor of 2.0. The higher strain levels are often used when it is necessary to achieve the same 3 mV/V calibration in the presence of dissipative compensating circuitry.
- **Uniform strain distribution in the strain gauge area:** Since the electrical output of the load cell is limited by the maximum allowable strain level in the gauge region, this strain level should exist uniformly over the entire area of the gauge grids to maximize the signal and to improve transducer performance. When it can be accomplished, having the solder tabs of the gauges lie on an area of lower strain will generally improve the fatigue life of the gauges.
- **Lower strain levels throughout the remainder of the spring element:** The strain magnitude in the gauged area of a spring element should not only be uniformly distributed and at the proper level to produce the desired full-load output signal, but normally it should also be the highest strain level anywhere in the entire spring element.
- **Design for ease of machining and gauge installation:** To be successful in the Market place, a load cell or other transducer must be competitively priced. The process of accomplishing this within the framework of imposed functional constraints offers the opportunity for considerable ingenuity in element design. There is little to be gained by meeting all of the other design criteria in this list if the resulting spring element is unduly difficult and expensive to machine. It is equally important to fully appreciate the economics of strain gauge installation.

4. EXPERIMENTAL PROCEDURE

4.1 Introduction

In this chapter we can show the application of fabricated strain gauge based load cell which itself is the practical case of the problem explained in the previous chapter. we can show any compression case as an application to the load cell but here we are taking drilling as an application because it is very easy to understand the case study.

If we consider drilling as an experiment, we need to place our fabricated load cell beneath the work piece where some fixture arrangement is there to hold the work piece tightly. Then we go for further process.

4.2 Application to the load cell

Step by Step Procedure for Interpretation Strain values by Using LAB VIEW Software:

APPARATUS

NI PXIe-1071 Chassis, NI PXIe -8101 Embedded Controller, NI PXIe -4492 Strain Module, PCB Accelerometer (Sensitivity 100.5 mV/g).

CONNECTIONS

1. Connect the power Cable of NI PXIe-1071 Chassis to power Socket.
2. Make interconnection between monitor to NI PXIe-1071 Chassis Using DVI-I(white) to VGA(Blue) splitter.
3. Connect Keyboard and Mouse (USB type only) to NI PXIe-1071 Chassis (direct connection or by using USB Hub).
4. Connect PCB accelerometer using INFINIBAND 4X-8BNC (8 pin cable) to NI PXIe-4492 Strain module.
5. Connect the PCB Accelerometer to the work piece or cutting tool while machining.

PROCEDURE

1. Open NI MAX (Measurement and Automation Explorer) to test whether the drivers are successfully communicated with the PXI slots (as shown in fig.1).

Right click on NI PXIe-4492 and self test and press ok.The following message will be displayed(as shown in Fig.2) if the drivers are connected successfully.

Now drivers are successfully connected to NI PXIe-4492 Strain module to NI PXIe-1071 Chassis.

2. Open LAB VIEW software, then go to **File → New Vi**(or CTRL+N) as shown in Fig.3,

Two windows will be opened called FRONT panel(on left side) and BLOCK diagram panel (on right side), (press CTRL+T to appear both panels side by side) as shown in fig.4.

Block diagrampanel is used to setup connection between NI PXIe-4492(PCB accelerometer) and NI PXIe-1071.

Front panel is used to display the outputs in the form of graphs indicators and Numeric indicator

From the above Fig. 4.3.1 it is shown that the graph is obtained between Time and Amplitude for the strain which i had loaded on the strain gauge.

5. CONCLUSIONS

The results obtained in this study lead to conclusions for the load cell after conducting the experiments and analyzing the resulting data

(1) In addition to being the key to the experimental stress analysis, strain can be made an digital for essentially any kind of various mechanical type inputs like force, to the engineer .for this reason strain gauges are widely and successfully used as secondary transducers in measuring systems of all types. Their response characteristics are excellent and they are reliable, relatively linear and inexpensive.

(2) Strain gauge load cell for loads upto15000 kg was realised which we can use at small scale industries and in the cases where size of the load cell is limited

(3) Essential elements in the design of the load cell are the Belleville springs which is a conical shaped disc that will deflect at a given spring rate when subjected to an axial load. This rate is usually very high relative to a other springs, which makes a Belleville an excellent candidate where large loads must be delivered through a short movement

(4) These strain gauge load cell tend to have long life cycles in application but these can fail with high dynamic loading cycles.

(5) A microcrystalline wax layer was applied which, is the most effective organic barrier material currently available for protecting strain gauge circuits from moisture

REFERENCES

[1] Baoxiang He, Guirong Lu, Kaibin Chu, Guoqiang Ma,(2009) “Developing of High Accuracy and low Capacity Strain Gauge BasedLoad Cell for electronic Scale”, The Ninth International Conference on Electronic Measurement & Instruments, IEEE 2009, pp. 2-252

[2] Michel M. Madsen and Jorgen French, Mechanical design of strain gauge based load cell

[3] Guide for Load Cells, WELMEC European cooperation in legal metrology.

[4] A Procedure for the Specification, Calibration and Testing of Strain Gauge Load Cells for Industrial Process Weighing and Force Measurement, Institute of Measurement & Control, London.

[5] NCWM Publication 14, National Type Evaluation Program Administrative Procedures, Technical Policy, Checklists, and Test Procedures, Section 2, Chapter 5, Checklist for Load Cells

[6] Nakagiri Isa and Toru Kohashi, Simplification of Structure and Improvement of Weighing Accuracy for Multi-hopper , Japan, IEEE-2008, pp.1024