Bend Sensor® Technology Mechanical Application Design Guide

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Bend Sensor® Mechanical Application Guide

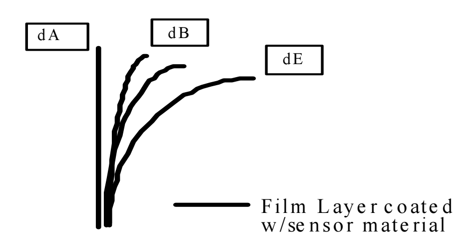
Introduction

This Application Guide is designed to help mechanical designers build interfaces that result in the successful integration of Bend Sensor® components into products. Flexpoint Sensor Systems (Flexpoint) has successfully developed and marketed products incorporating Bend Sensor® technology. As described below the Bend Sensor® device is typically a film – the Bend Sensor® film is put into a system and essentially "goes along for the ride". The film is attached to a system and measures the movement of the system. Although the sensor itself is capable of being cycled millions of times, the system it is applied to must also be robust. Below is a description of the sensor, and many of the considerations that should be understood in the design of the system.

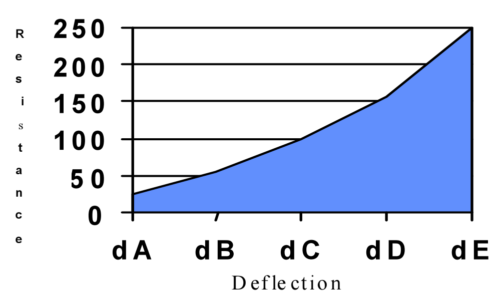
Description of the Bend Sensor® Device

The Bend Sensor® potentiometer is a product consisting of a plastic substrate coated with a resistive material that changes in electrical conductivity as it is bent. Electronic systems can connect to the sensor and measure with fine detail the amount of bending or movement that occurs. Depending on the configuration and integration of the sensor resistance changes of greater than 10 times can be realized. Refer to the Bend Sensor® Electronic Design Guide (http://www.flexpoint.com/wp-content/uploads/2015/05/electronicDesignGuide.pdf) for a description of electronic interfaces.

An example application is one where a sensor is attached to a hinge. As the door is opened, among other things one can measure how far the door is opened and how fast it is moving. The sensor is lightweight, small, easily packaged and very reliable. The breadth of the application for the Bend Sensor® device is limited only by the customer's imagination.



Deflection of the sensor may be achieved through many mechanical options.



Resistance (k ohms) vs. Deflection of Sensor

The rate of change as displayed in the graph is dependent on two factors. The first is the bend radius, the smaller the radius the greater the change. Secondly is the angular deflection. For a given radius the more the sensor is bent around it the greater the change.

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How the Bend Sensor® Potentiometer Works

Flexpoint's patented Bend Sensor® device consists of a single layer, thin, (0.005" typ.) flexible piece of material that is coated with a proprietary carbon/polymer based ink. This type of resistive element is commonly used to make thick film resistors, resistor networks, slide potentiometers and transducers. Flexpoint's proprietary inks are primarily printed on thin plastic films.

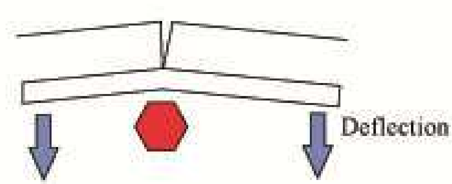
Flexpoint uses a coating that when printed on a plastic film such as polyimide forms a bond that is very strong. The ink is very hard and brittle. During processing micro cracks are introduced into the carbon/polymer coating, when the coated film is bent, the ink's many micro cracks, which upon movement open and close to the specific bending of the material. The ink maintains its integrity in shape and continues to have a very strong bond to the substrate. One of the most unusual characteristics of this ink occurs when the material is bent over a given radius repeatedly. It returns to its original value within the same slope or curve of resistance proportional to displacement.

The sensors are easily customized as the coatings can be applied in many patterns to adjust the resistance and can be screen printed as required by the application. The tremendous reliability, consistency and repeatability of the Bend Sensor® device make it highly desirable to many industries. Other technologies such as force sensors do not display and deliver the reliability and versatility of the Bend Sensor® potentiometer.

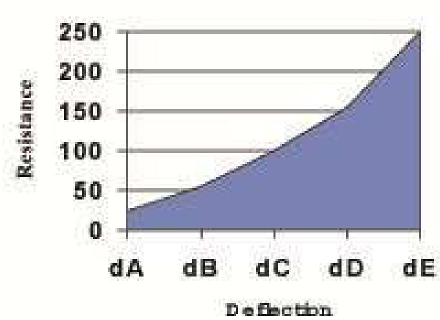
As mentioned the Bend Sensor® is a single layer construction. As such dirt, dust and other particulates that cause issue with multiple layer sensors do not affect the Bend Sensor®. The same is true for many liquids including gasoline, diesel fuel, motor oil, antifreeze, alcohol and water to name a few.

Since the coating can be placed on several types of substrates, the sensor may be designed to act as its own spring allowing the sensor to return to its original position.

The proprietary inks are custom manufactured by Flexpoint and can be easily adjusted to the specific resistance requirements of the customer. Flexpoint can design the method of actuation or bending to fit the measurement needs. New inks and products are constantly being developed.



As the sensor is bent micro cracks separate and resistance increases.



Resistance (k ohms) vs. Deflection of Sensor

The Bend Sensor® Device

Base Materials –

- Can be printed on several substrates – is primarily printed on a plastic film such as polyimide. Contact the factory for the specifications on the materials used.
- The Bend Sensor® can be printed on both sides allowing the sensor to give readings in both directions and can delineate the direction of the bend as well as magnitude.

- The base material determines such factors as environmental stability, changes in resistance, durability, and costs. Polyimide films are required for wide temperature operating ranges and extreme durability – but may vary in cost depending on the geometry of the sensor.

Specifications:

Polyimide –
Storage Temperatures: -60ºC to +110ºC @ 90% RH typ.
Operating Temperatures: -40ºC to +90ºC @ 90% RH typ.
Polyester –
Storage Temperatures: -40ºC to +100ºC @ 90% RH typ.
Operating Temperatures: -30ºC to +90ºC @ 90% RH typ.

Environmental Stability –

- The base material is an important factor in determining the ultimate environmental stability of the sensor. Thermal coefficients of expansion of the base material and the product the sensor is being placed in should be considered.

- Single layer construction and pliability of the base material helps keep the sensor stable in many environmental conditions; even surprisingly extreme conditions.

- Unlike competing sensors, the sensor is nicely able to withstand exposure to humidity, moisture and many other fluids.

- The sensor can be environmentally protected in many ways including the following:
    - Laminate a protective layer over the sensor coating – multiple laminate types are possible
    - Coat the sensor with rubber, silicone, or urethane.
    - Seal the sensor in a plastic sleeve.

Base Resistance –

- Has a finite base resistance which, depending on geometry and design, can be as low as 100 Ω and as high as 500 KΩ.

- Its base (flat state) resistance is adjusted by changing the active geometry of the sensor – doubling the length will double the resistance or doubling the width halves the base resistance. Another method for adjusting base resistance is to add a conductive pattern over the sensor area to reduce the resistance.

- It is important to remember that when used in a voltage divider network the fixed resistor should be as close to the geometric mean of the actuated sensor and the base resistance of the sensor as possible. The easiest way to use the Bend Sensor® Device is by installing it as part of a voltage divider network. Other processors have made the voltage divider unnecessary being able to connect the sensor directly to a constant current DAC. Refer to the **Bend Sensor® Technology Electronics Interface Design Guide** for more information.

Radius of Curvature –

- When wrapped around a mandrel of a given diameter, for any given arc length, the resistance can increase by more than 10 times. It is dependent on the mandrel diameter, or in other words, the radius of curvature of the Bend Sensor® Device.

- The smaller the radius of curvature the sharper the bend, and therefore, the greater the rate and magnitude of increase in the resistance of the Bend Sensor® Device.

- Many factors, such as the geometry of the printed coating, the base substrate thickness, the type of overlaminate that is used, and the method of actuation will also affect the amount of the increase in resistance.

  Specifications:
  Test set up – 0.28" x 1.00" sensor wrapped around a 3/8" diameter mandrel using a 0.005" thick polyimide substrate.
  Base Resistance: 2,000 Ω ± 25%
  Resistance while wrapped around mandrel: 140k Ω ± 25%

- Once again, the base resistance, rate of change, and total change are affected by coating geometry, substrate thickness, type of overlaminate used, and method of actuation. It is best to test the Bend Sensor in your actual application to get accurate data for your design.

Spring and Actuator –

- It is critical to consider the fact that the sensor is typically attached to a moving device and simply "goes along for the ride." The sensor has been attached to plastics, metals, rubbers, and other materials by means such as pressure sensitive adhesives, stitching, and heat staking.

- When attached to any other material the sensor takes on the mechanical properties of that material.

- In order to have a repeatable system, the actuator, or mechanical device to which the Bend Sensor® Device is attached, needs to be repeatable in any action. An example of a repeatable mechanical device is that of a spring working below its yield point for a single actuation, or below its fatigue point for repeated actuations.

- For most situations, a Bend Sensor® Device will be attached to any of three "spring" configurations. The first one is that of a cantilever beam, the second is a simply supported beam, and the third is a beam simply supported on one end and fixed at the other end. The sensor will need to be installed on the side of the apparatus that will yield the greatest tensile displacement. See attached figures 1 through 3 for examples.

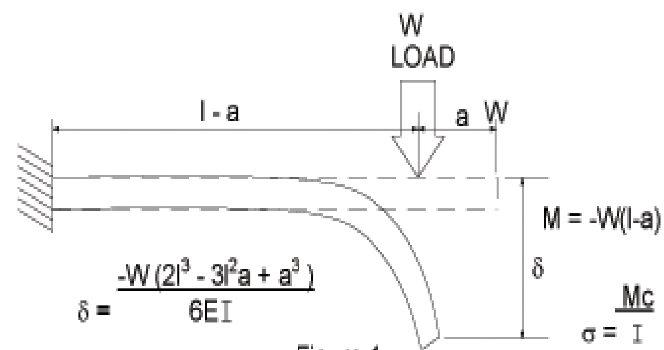


Figure 1

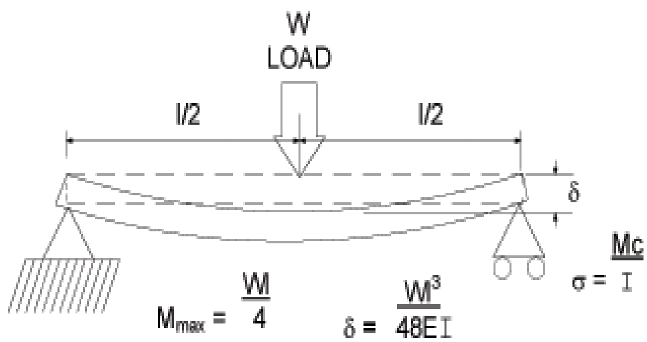


Figure 2

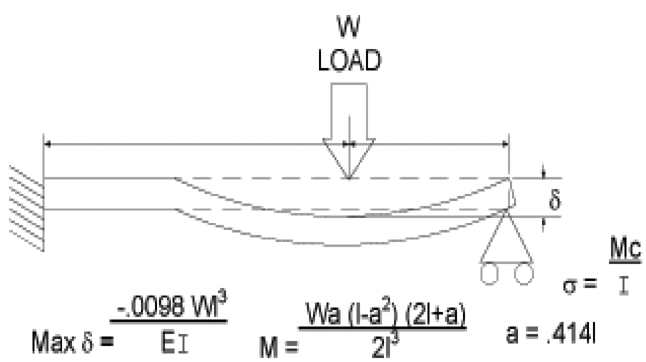


Figure 3

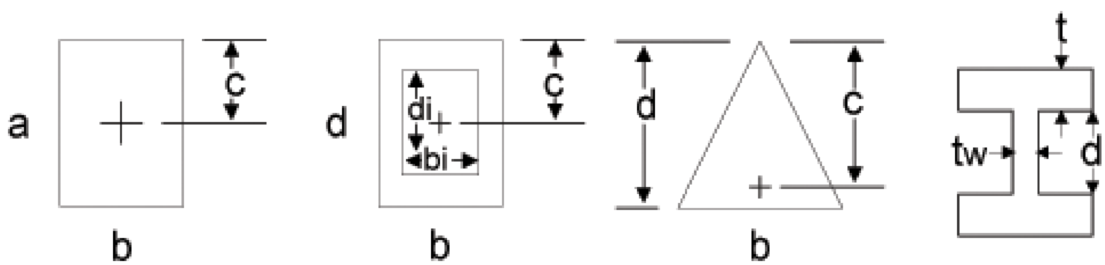
- In each figure, a set of equations is found to predict the 'spring' or beam deflection as well as the maximum stress the beam will experience at the given deflection.
- Figure 4 shows the definitions of the terms used in the equations. Figure 5 gives some of the properties of the more common materials as well as the Mass Moments of Inertia for the common beam cross sections.

l	=	total beam length
a	=	distance from one end to load position
w	=	load
δ	=	deflection of beam after load is applied
M	=	moment, used in the determination of stress
σ	=	stress found in the outer beam fibers
I	=	mass moment of inertia of beam

a, b, c, d, t, bi, di, tw = geometric distances used for defining beam cross sections

Figure 4

BEAM CROSS SECTIONS



$$I = \frac{ba^3}{12} \qquad C = \frac{a}{2}$$

$$I = \frac{bd^3 - bidi^3}{12} \qquad C = \frac{d}{2}$$

$$I = \frac{bd^3}{36} \qquad C = \frac{2d}{3}$$

$$I = \frac{b(d+2t)^3}{12} - \frac{(b-tw)d^3}{12} \qquad C = \frac{d}{2} + t$$

E - Youngs Modulus of Elasticity

Aluminum	10×10^6	Polyimide	37×10^4
Steel	30×10^6	Polyester	65×10^4
Copper	17×10^6	PEN	87×10^4

Figure 5

Summary:

There are many methods that can accomplish the successful implementation of the Bend Sensor® product into an application. Further, it is important to consider the design of the electronic interface to be used with the sensors. For information regarding the design of the electronics for the sensor to be used in your system refer to the Bend Sensor® Technology Electronic Interface Design Guide:

(http://www.flexpoint.com/wp-content/uploads/2015/05/electronicDesignGuide.pdf.)

If you have any questions, please call Flexpoint Sensor Systems (801) 568-5111 or contact us at info@flexpoint.com.