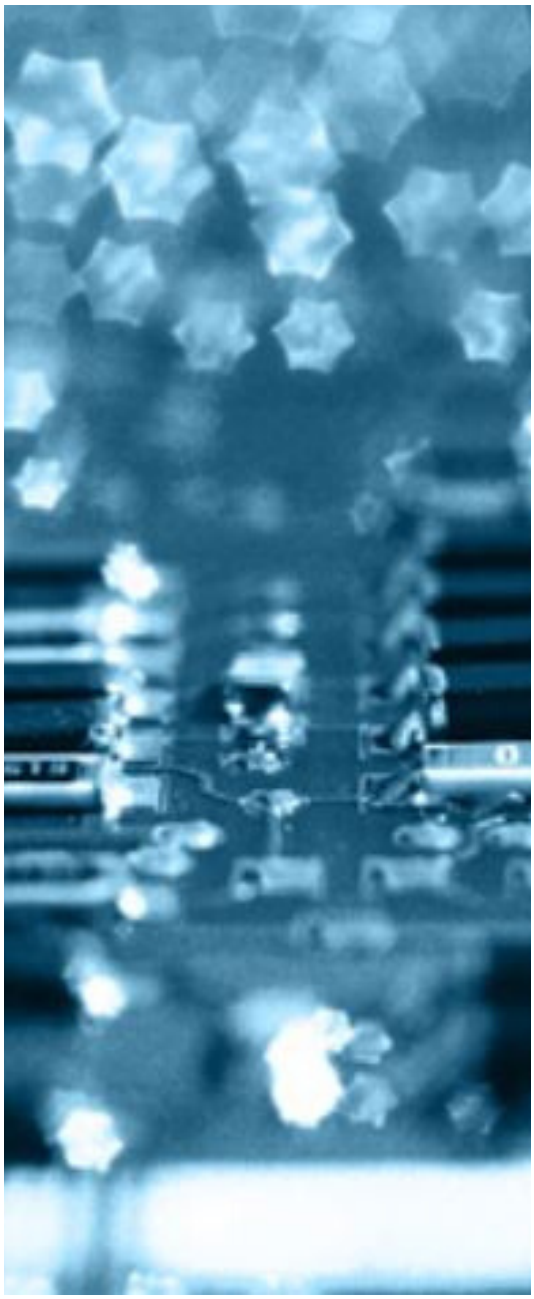
STRAIN GAUGES

WHAT | WHY | HOW | ABOUT STRAIN GAUGES

INTRODUCTION

ZEMIC EUROPE HAS OVER 50 YEARS OF EXPERIENCE IN DEVELOPING, PRODUCING AND SELLING STRAIN GAUGES.



By applying a strain gauge to a material, we can measure the stress in the material, the changes in shape or when strain occurs. When you start measuring with strain gauges it is useful to know the relationship between stress, force and strain.

The resistance of a strain gauge will change when there will be stress in the material or stress and / or pressure will be exerted externally onto the material. The amount of strain can be read directly with a (strain) measuring instrument.

Stress is caused by a mechanical force. Mechanical stresses are not accessible for direct measurement. Normal stresses (tension/compression) are calculated either with
the theoretical values of the material or from strain (gauge) measurements. The way to do this, is by using Hooke's Law.

Zemic Europe has over 50 years of experience in developing, producing and selling strain gauges.
This is the heart of the weighing and force industry and is used in so many products. We therefore felt it was important to write a whitepaper on this subject, in which questions such as:

- What is a strain gauge
- Why do you use a strain gauge
- How a strain gauge works
- Materials and properties
- How to bond strain gauges
- How to make a choice of a strain gauge

Will be explained shortly and to the point so that you know the basics of the weighing and force
industry. Please know that if you want more information about strain gauges or Zemic Europe we are there for you. Feel free to contact us and ask us about this topic!

Enjoy reading.

INDEX

Download the strain gauge catalogue of Zemic Europe here.

If you have any questions, feel free to contact us:
info@zemic.nl or (+31) 76 5039480

WHAT IS A STRAIN GAUGE?

A STRAIN GAUGE IS AN ELECTRICAL ELEMENT THAT MEASURES THE DEFORMATION OF A MATERIAL. THIS CAN BE BY MEANS OF TENSION / COMPRESSION, TORSION, SHEARING OR BENDING. BY MEASURING THIS DEFORMATION, YOU CAN DETERMINE WEIGHT AND FORCES. THE APPLICATIONS ARE INFINITE.

The origin of a part of the theory behind strain gauge technology goes back to the 17th Century. During that time London was being rebuilt after the Great Fire of 1666. A great amount of research took place on the strength of materials when building and reconstructing London. Robert Hooke took a leading part in this work and extended his researches to include an investigation of elasticity in general. He came to the conclusion that when the elastic limit of a material is not exceeded the deformation of a material is proportional to the force applied to it. Or as he succinctly phrased it:
"Ut tension sic vis"
(Literally: as the stretching thus the force.)

A strain gauge is an electrical element measuring the deformation of a material, from any material you can think of. The electrical resistance of most strain gauges is changing during the following conditions.

Mechanical strain:
the effect of an applied external force. This will cause strain gauges to register a deformation in the material which will make it change signal.

Thermal strain:
the influence of heat and cold. All material react when it is heated up or when it cools down. This will also cause strain gauges to register a deformation in the material which will cause a signal change.

Residual strain:
internal forces from the non-uniform cooling of cast components, forging, or welding. There are methods available to relieve the residual stress in an object thus removing the residual strain.

The electrical resistance element consists of an electrically conductive material, the grid pattern is photo etched on a non-conductive backing foil. This backing foil is connected to the structure from which the strain is to be measured. Typical strain gauge resistances range from 30 to 5000 Ω, with 120 Ω, 350 Ω and 1000 Ω being the most common values.

HOW A STRAIN GAUGE WORKS?

TO UNDERSTAND HOW STRAIN CAN BE MEASURED, FIRST YOU HAVE TO UNDERSTAND THE EFFECTS OF STRAIN ON THE MATERIAL. THE STRAIN CAN BE DEFINED AS THE RATIO OF THE CHANGE IN LENGTH OF THE MATERIAL TO ITS ORIGINAL LENGTH.

Strain $\varepsilon = \frac{\Delta L}{L_o}$

The common unit of strain is the micro strain 10^{-6} µm/m

Years later Thomas Young quantified Hooke's work in the relationship:

$\frac{Stress}{Strain} = E_m$ where E_m is Youngs' Modulus

Completely separate research in the 19th Century led Lord Kelvin to identify the relationship between strain and the change in resistance of a resistive material. He showed that for certain materials, the resistance is directly proportional to its length and inversely proportional to its cross-sectional area. This relationship can be interpreted by:

$$\frac{\Delta R}{R_o} : \frac{\Delta L}{L_o}$$

It was the combination of these two relationships which enabled Simmons (California Institute of Technology) to independently produce the first strain gauges in 1937. By bonding a piece of resistive wire to the transducer element by means of a carrier or backing, the force applied to the element could be identified in terms of resistance change. This change in resistance can then be converted to a usable electrical signal which is proportional to the applied force.

These early strain gauges had backings made from ordinary paper impregnated with a cellulose glue as a carrier for the resistance wire. These were then bonded to the transducer with the same glue. The early resistance wire had a diameter of 20 µm but today, gauges are etched from metallic foil with a thickness of 5 µm. The gauge backing and adhesive play a crucial role in determining the performance of load cells. Today special plastics are used as backing with a thickness less than 50µm together with special adhesives which have to be cured at critical temperatures. Typical glue thicknesses are between 5 – 10 µm.

When the strain gauge is stretched, the length of the electrical conductor increases while its cross section decreases with compression, the opposite happens. Both of these effects increase the electrical resistance of the conductor. Strain gauges are subjected to either tensile or compressive strain of a few percent, in special cases up to 20%.

Usually, strain gauges are used in a so-called Wheatstone bridge configuration. In this configuration, four or a multiple of four strain gauges are used. This way, the signal measured by strain gauges can be increased by four. In addition, the output signal of the Wheatstone bridge is in mV/V and can therefore be measured with a simple indicator.

WHY USE A STRAIN GAUGE?

IN SHORT, STRAIN GAUGES ARE USED FOR TWO DIFFERENT APPLICATIONS:

- SENSOR PRODUCTION
- STRESS ANALYSIS

Usually the strain is measured to determine the stress in the material. The absolute value and direction of the mechanical stress is determined based on the measured strain and the known characteristics of the material (modulus of elasticity and Poisson ratio). These calculations are based on Hooke's law. In its simplest form, Hooke's Law determines the direct proportionality of the strain ε [m/m] and the stress σ [N/mm2] of a certain material using Young's modulus E [N/mm2].

$\sigma = \varepsilon \cdot E$

Sensor production

Zemic Europe offers over 1000 standard force sensors. Force sensors equipped with strain gauges are applied for weighing applications and applications where forces are to be measured.

A few examples for weighing applications are:

- Laboratory scales
- Retail scales
- Hopper scales
- Silo weighing
- Weighbridges
- Platform scales
- Pallet scales.

A few examples of applications where forces are to be measured:

- Electrical bicycles – forces are used to adjust the power of the motor
- Ergonomic solutions – forces are used to assist the amount of power that needs to be applied
- Automobile applications – forces are measured to ensure safety
- Elevators – overload detection and protection
- Optimizing designs – to optimize the quality of construction

Stress analysis

Strain gauges are used for experimental stress analysis. Often, we see strain gauges are used for testing and measurement. Here are few examples of how Zemic strain gauges are used:

Force localization: what parts on a material are the weakest?
We refer to our exoskeleton case study on our website www.zemiceurope.com as a nice example.

Force determination: what force is being applied where?
For example for bridge and construction sites.

WHAT DOES A STRAIN GAUGE CONSIST OF?

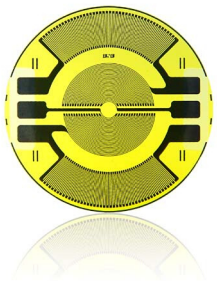
STRAIN GAUGE CONSISTS OF THE FOLLOWING ELEMENTS:

There are different kind of grids: Electrically conductive material

- Constantan (B)
- Karma (Z)

Backing foil;

- Modified Phenolic (F)
- Polyimide (A)
- Modified Epoxy (H)
- Polyimide film (AM)
- Glass fibre reinforced epoxy (HB)
- Glass fibre reinforced polyimide (AB)
- Special thin polyimide film (YM)



Grid: constantan (B)
Copper nickel alloy. Most widely used and has the best combination of properties for use as a grid material.

Grid: Karma (Z)
Nickel chrome alloy. It has better fatigue factor than constantan and can be used up to higher temperatures. The disadvantage is that karma is hard to solder.

Backing foil: Modified Phenolic (F)
Used to withstand higher temperatures. Is an improved version of the Polyimide backing

Backing foil: Polyimide (A)
The most commonly used material for strain gauge backing. Stable, very durable and flexible. Can be used at a wide temperature and can stretch up to 20% of the original length.

Backing foil: Modified Epoxy (H)
Is a backing of glue. Used for lower temperatures. Is a fairly brittle material. There is less control over thickness during production so there is more creep.

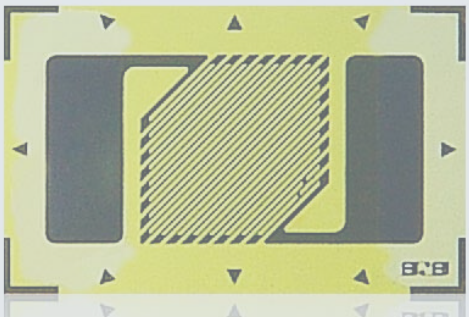
Backing foil: Polyimide film (AM)
Same as Polyimide, only thinner layer. Less creep and better transfer of strain.

Backing foil: Glass fiber reinforced epoxy (HB)
Same as Epoxy but has a greater resistance to breakage when deformed. Provides a more homogeneous material.

Backing foil: Glass fiber reinforced polyimide (AB)
Polyimide for higher temperatures. Keeps the backing better in place. Has a higher creep resistance.

Backing foil: Special thin polyimide film (YM)
Special extra thin polyimide film backing that has better strain transfer. Has high heat resistance. Mainly used for high accuracy load cell transducers.

On www.zemiceurope.com we offer a strain gauge selector. By filling in this selection you are building up your strain gauge from scratch. We are also available to help you with the correct selection.



CHOICE OF STRAIN GAUGE

DOWNLOAD THE STRAIN GAUGE CATALOGUE FROM ZEMIC EUROPE HERE FOR MORE INFORMATION ABOUT THE BEST CHOICE OF STRAIN GAUGE.

The choice of strain gauge is based on the usage, the important technical parameters and the options available per series and geometry. Most important is the required accuracy which you want to achieve. For experimental stress analysis, the testing conditions are also key to choosing a strain gauge. In choosing the right strain gauge you should also consider the material on which the strain gauge is placed, the temperature and the environment.

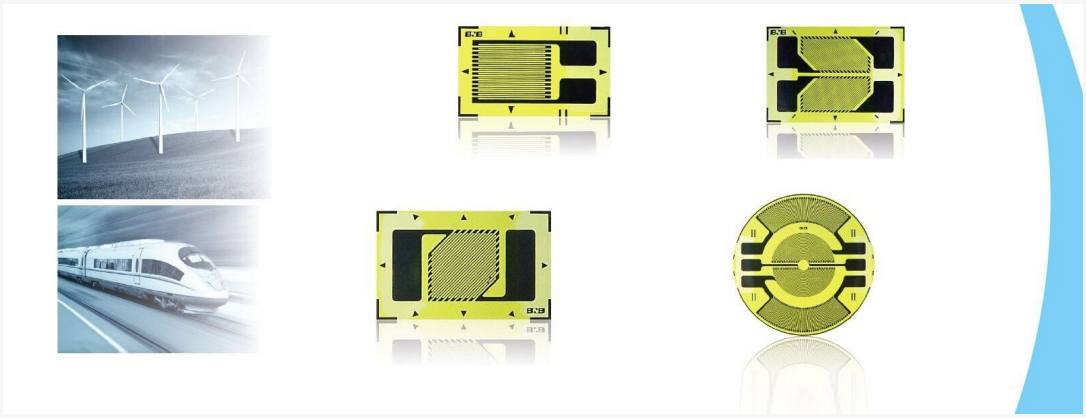
For force sensors machining an element it is important to undertake stabilizing treatments to release any residual stress or internal stress to make the performance more stable. In addition, it is important to realise that making force sensors is a specialism requiring workmanship skills.

When strain gauges are delivered it is important to check them before starting the gauge bonding.

First of all, it is important to check the gauges for possible damages to the backing, grid lines or any other part of the strain gauge. Strain gauges are highly sensitive because of the thin layers and precise way of measurement. It is also advised to check the strain gauge resistance which should be accurate up to 0,1Ω.

In short, to make a good choice: size, geometry and temperature are very important.

For the best advice it is always possible to contact Zemic Europe and we will help you find the best solution.



HOW TO BOND STRAIN GAUGES?

Selecting the correct adhesive is just as important as choosing the right strain gauge. The decision of adhesive is dependent on what the strain gauge is used for, what the external conditions of use are and for what period of time. Zemic Europe advise H-610 or H -600 for the production of load cells. When the adhesive is delivered it is important to check the adhesive before starting the gauge bonding.

Before you start using the adhesives it is important to read the material safety datasheet. You can also check the glue on 3 subjects. Firstly, it is important to check what the expiration date of the adhesive is. Please note that sometimes the date indicated on the bottles is the production date. When the expiration date has passed the adhesive has lost a part of its bonding strength. Secondly it is important, when a two-component adhesive is ordered if both components are delivered. Thirdly it is wise to check when a two-component adhesive is delivered if the ratio is correctly noted on the bottles.
You have to follow the bonding and protecting procedures stated below. For more information about the procedures below,please check the Zemic Europe strain gauge catalogue.

BONDING PROCEDURES:

- SELECTING STRAIN GAUGES
- SELECTING BONDING ADHESIVE
- SANDING ELEMENTS
- LINING AND LOCATION
- SURFACE CLEANING
- GAUGE CLEANING
- APPLYING ADHESIVE
- GAUGE BONDING
- HEAT CURING
- QUALITY CHECK AFTER CURING
- SOLDERING LEAD WIRES
- QUALITY CHECK OF SOLDERING
- COMPENSATING AT NORMAL TEMPERATURE AND TEMPERATURE PERFORMANCE
- QUALITY CHECK OF COMPENSATION
- TESTING AND TESTING PERFORMANCE
- APPLYING PROTECTION

For further explanation for procedures we advise you to contact us.

LEADING MANUFACTURER OF STRAIN GAUGES

ZEMIC is one of the leading manufacturers of strain gauges. With over 50 years of experience in the development and production of strain gauges, ZEMIC produces a high quality and wide variation of strain gauges in high volumes. With our experience and development expertise, ZEMIC has become one of the largest manufacturers of strain gauges.

Zemic Europe, the manufacturer leader in strain gauge technology

Zemic Europe takes care of the sales, marketing and development within Europe. Zemic Europe is a centre of competence within the weighing industry and is able to supply everyone with the
best solution for their stress analysis and weighing applications.

ZEMIC strain gauges are produced according to the RoHS environmental directives. All ZEMIC strain gauges are in accordance with the needs for sophisticated stress analysis and high-precision strain gauge sensors.

Technology and quality of foil gauges

With sustainable and efficient technology research and development systems, ZEMIC upkeeps the strict quality assurance system. With professional and reliable technology ZEMIC is able to produce an annual output of over 50 million stable, reliable and first-class quality strain gauges which are divided in more than a dozen series and over a thousand different specifications.

WE BELIEVE WE MAKE YOU STRONGER!

AFTERWORD

Strain gauges is a topic we can tell you more about. Dependent on the project or product you will require. We always like to discuss this with you so we can find the best strain gauge / application match together. On our website you will find more information about this interesting topic!

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