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EXPERIMENTAL RESEARCH OF TOTAL DEFORMATION AND EQUIVALENT STRESS FOR INTERNAL COMBUSTION ENGINES COMPONENTS

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Abstract: *For calculating and dimensioning of internal combustion engine, particular attention is given to crank mechanism. Forces acting on it are those exerted by gas pressure and inertia of masses moving mechanism. After determining the maximum values of these forces, necessary step for dimensioning the crank mechanism, experimental research can be performed for an given engine components. Results of measurements can be compared with those of finite element analysis performed with ANSYS software. There are presented results from measurements using strain gauges and finite element analysis for piston and connecting rod of the MDR-2 engine.*
Keywords: *piston, connecting rod, strain gages.*

1. INTRODUCTION

The strain gauge has become an essential tool in stress analysis, part optimization, safety testing and technical investigative work. It is also a major component used in the manufacturing of measurement transducers. While there are several methods of measuring strain, the most common is with a strain gauge, a device whose electrical resistance varies in proportion to the amount of strain in the device. The metallic strain gauge consists of a very fine wire or, more commonly, metallic foil arranged in a grid pattern. The grid pattern maximizes the amount of metallic wire or foil subject to strain in the parallel direction (Figure 1). The cross sectional area of the grid is minimized to reduce the effect of shear strain and Poisson Strain. The grid is bonded to a thin backing, called the carrier, which is attached directly to the test specimen. Therefore, the strain experienced by the test specimen is transferred directly to the strain gauge, which responds with a linear change in electrical resistance [4].
Measurements using strain gages is also an efficient method for determining the deformation for the components of rod crank mechanism. In the following are presented some aspects of deformation measurements of MDR-2 engine piston and connecting rod.

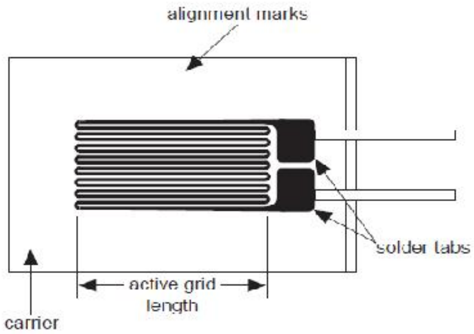
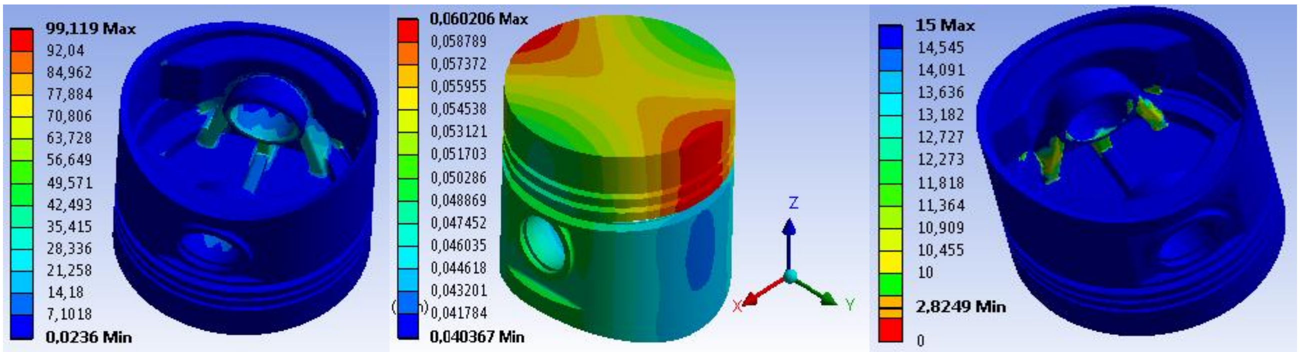


Figure 1: Bonded Metallic Strain Gauge

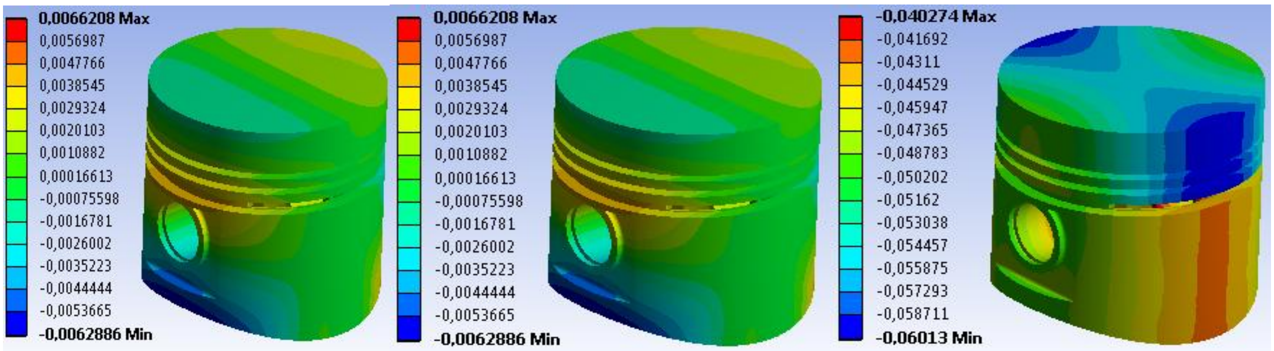
2. FINITE ELEMENT ANALYSIS OF THE PISTON AND CONNECTING ROD

Piston is one of the main parts in the engine. Its purpose is to transfer force from expanding gas in the cylinder to the crankshaft via a connecting rod. In finite element analysis of the piston MDR-2, mesh was achieved using tetra type elements, resulting 500971 nodes. In this case, the force exerted by the gas pressure was considered to be equal to 10000 [N] and applied evenly onto the piston surface. Analysis results when material used is ATC Si12CuMgNi an fixed support is defined by bearing boss of the piston pin can be seen in Figures 1,..., 3.



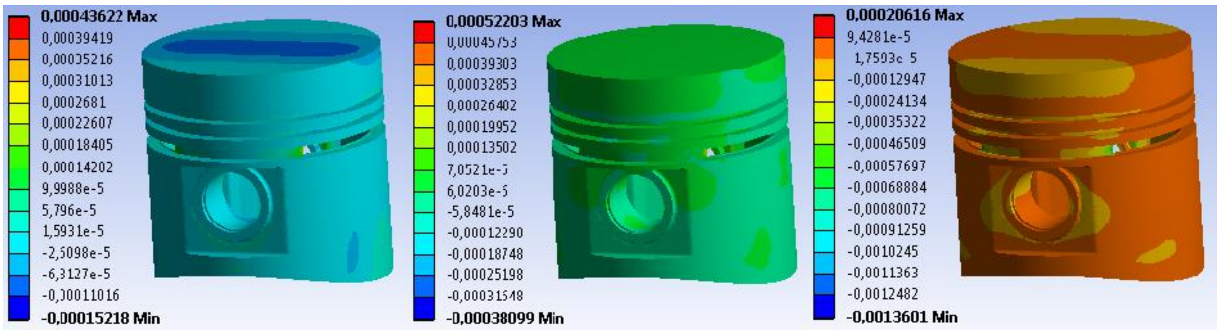
a) b) c)

Figure 1: Echivalent stress (von-Mises) [Mpa] (a), total deformation [mm/mm] (b) and safety factor (c) for the piston



a) b) c)

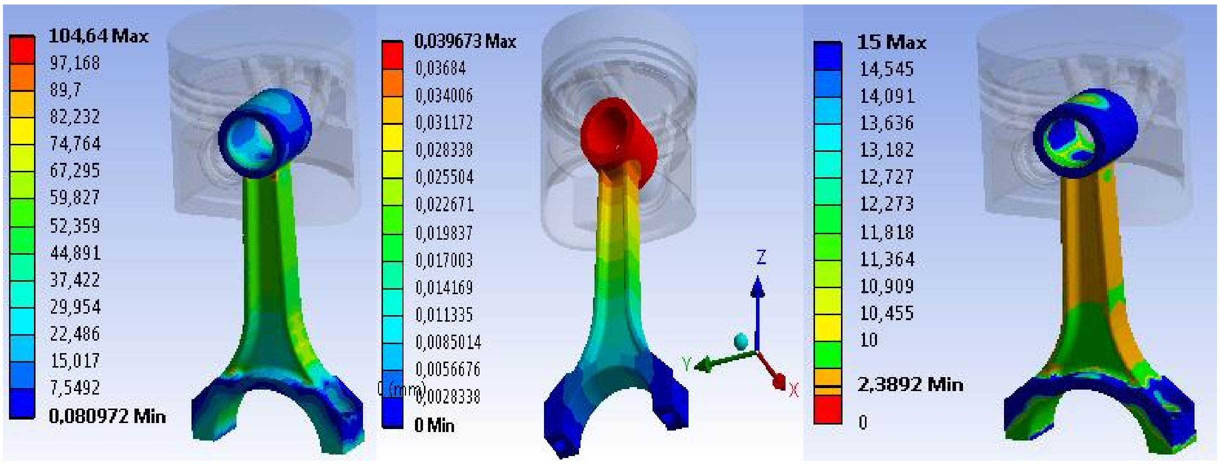
Figure 2: Directional deformation of the piston [mm/mm]: a) X axis; b) Y axis; c) Z axis



a) b) c)

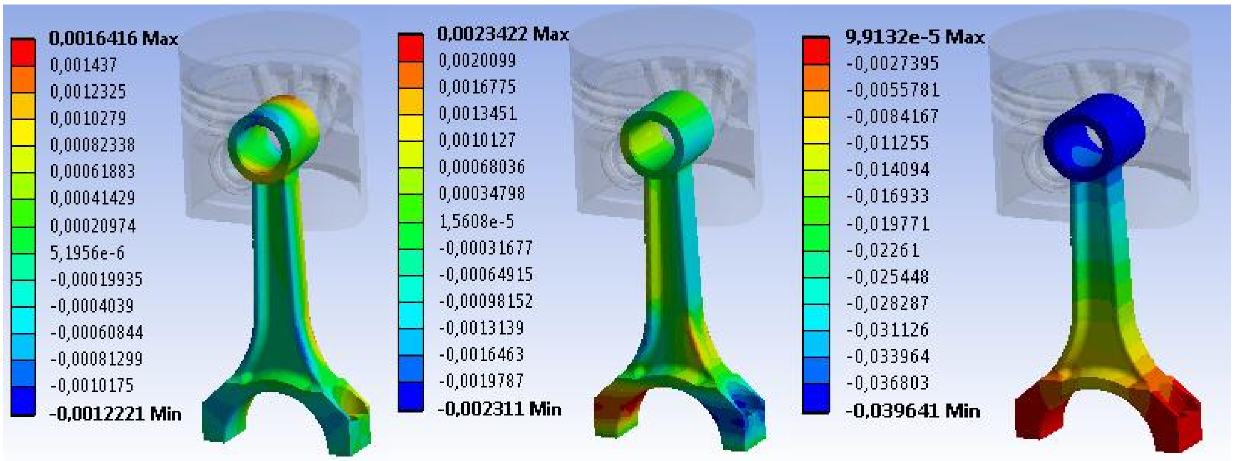
Figure 3: Normal elastic strain [mm/mm]: a) X axis; b) Y axis; c) Z axis

The connecting rod is a major link inside of a combustion engine. It connects the piston to the crankshaft and is responsible for transferring power from the piston to the crankshaft and sending it to the transmission. There are different types of materials and production methods used in the creation of connecting rods. For analyzing connecting rod of MDR-2 engine, in the previous analysis has been introduced its 3D model and material assigned was 41MoC11. The mesh for conrod was achieved using tetra type elements, resulting 55955 elements and 98785 nodes. Analysis results when fixed support is defined by conrod cap surface separation can be seen in Figures 4,..., 6.



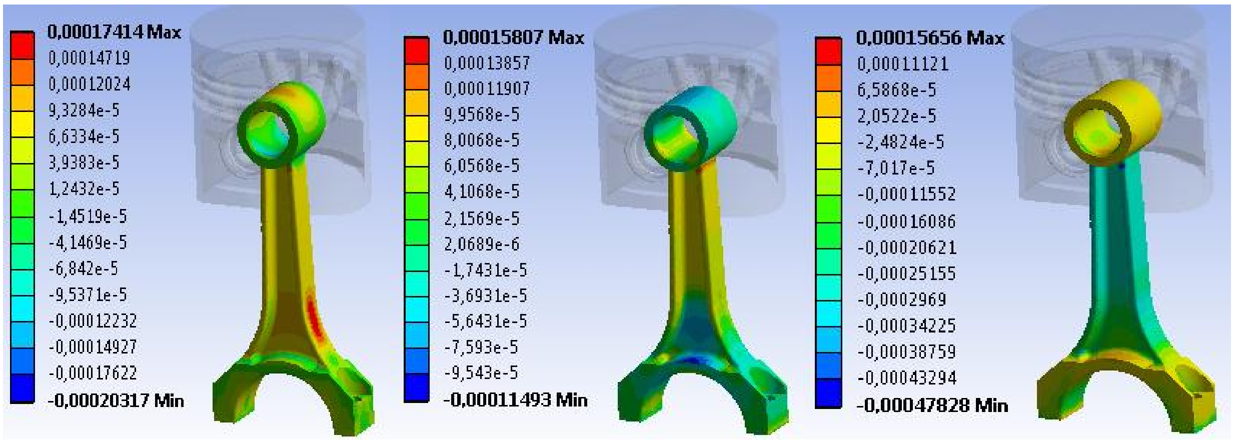
a) b) c)

Figure 4: Echivalent stress (von-Mises) [Mpa] (a), total deformation [mm/mm] (b) and safety factor (c)



a) b) c)

Figure 5: Directional deformation of the conrod [mm/mm]: a) X axis; b) Y axis; c) Z axis



a) b) c)

Figure 6: Normal elastic strain [mm/mm]: a) X axis; b) Y axis; c) Z axis

3. MEASUREMENTS USING STRAIN GAUGES

Equipment used for measurements is one that can be offered by VISHAY Micro-Measurements and includes strain gauge bridge – "Traveller StrainMaster" (Figure 7) – and data acquisition board – "Keithley" (Figure 8). Main characteristics of the strain gauges used are presented in Table 1.

Figure 7: Strain gauge bridge Traveller StrainMaster

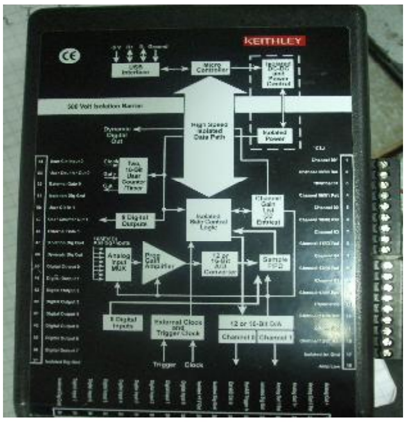


Figure 8: Data acquisition board Keithley

Figure 9: Different models for Con rod and piston tested

a) b)

Figure 10: Strain gauges attachements (a) and system arrangement on the compression machine (b)

Table 1

	Steel	Aluminium
Type	6/120LY11	6/120LY13
Resistance	120Ω±0,35%	120Ω±0,35%
Gauge factor	2,08±1%	2,08±1%
Transverse sensitivity	-0,1%	-0,1%
Temperature coefficient of gauge factor	104±10[10^{-6}/^{o}C] (-10,…, +45^{o}C)	126±10[10^{-6}/^{o}C] (-10,…, +45^{o}C)

The strain gauge for piston was attached on the inside surface of piston crown so that will be measured the deformations along Z axis (according to the axis system shown in Figure 1-b). The point where it was positioned corresponds to coordinates (-1,0661; 13,9; 192,7) on 3D model which is included in the cross section defined by points 1(46,2; 13,9; 192,7) and 2(-46,2; 13,9; 192,7) (Figure 11).
For connecting rod the strain gauge was attached on the outer half of the conrod body so that will be measured the deformations along Z axis (according to the axis system shown in Figure 4-b). The point where it was positioned corresponds to coordinates (0; -11,602; 100,5) on 3D model which is included in the longitudinal section defined by points 1(0; -10; 146,44) and 2(0; -12,774; 67) (Figure 12).
Measurement results for 10000[N] compression force acting on the system are presented in graphical form in Figures 13 and 14.

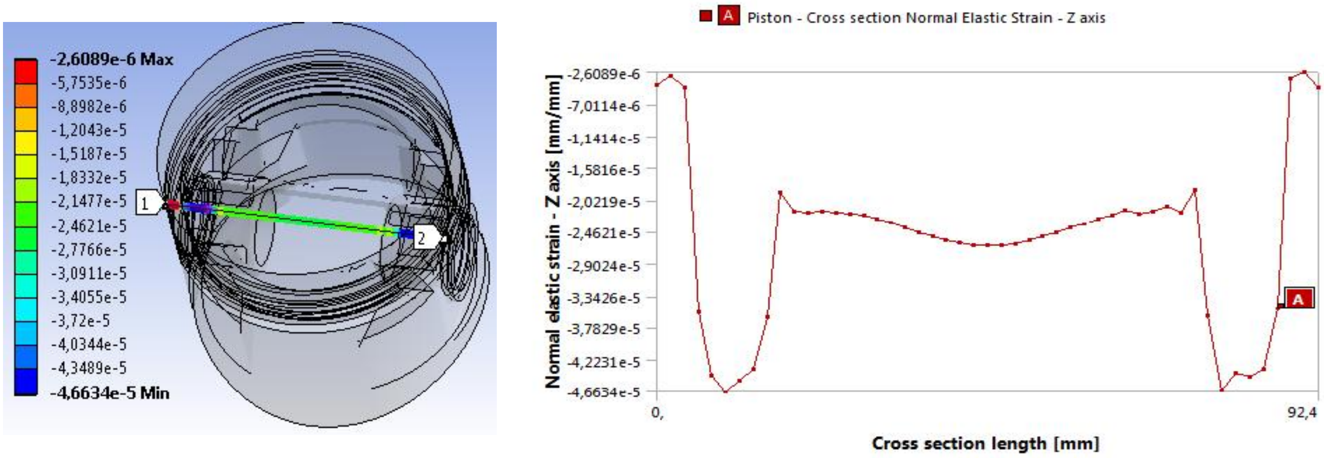


Figure 11: Normal elastic strain [mm/mm] – Z axis for cross section of piston

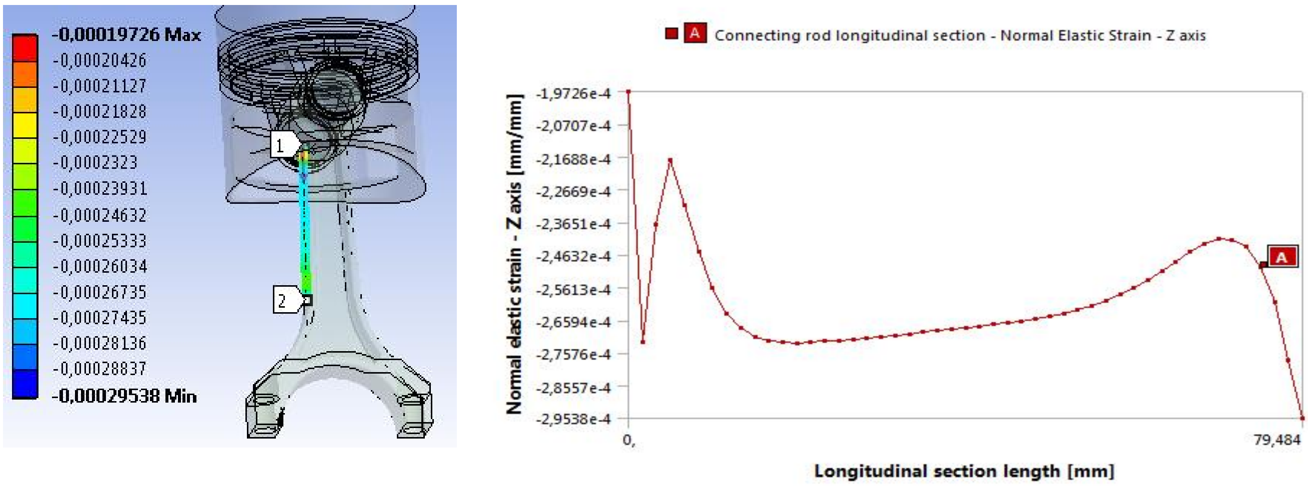


Figure 12: Normal elastic strain – Z axis for longitudinal section of connecting rod body

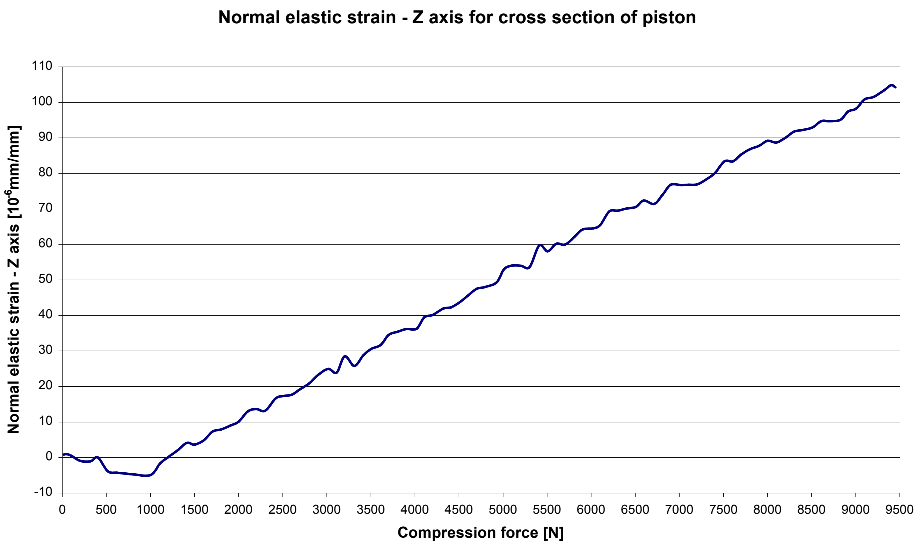


Figure 13: Normal elastic strain– Z axis [10^{-6}mm/mm] measured for cross section of piston

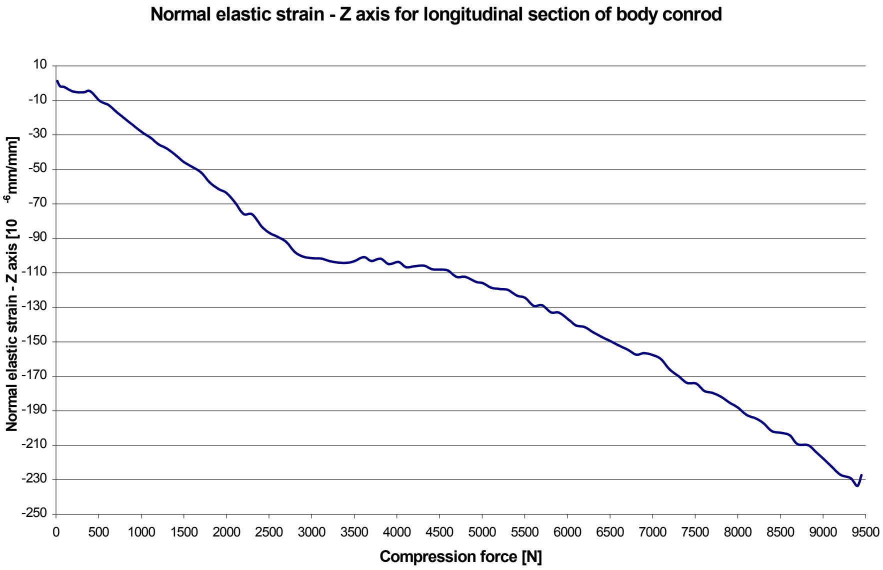


Figure 14: Normal elastic strain– Z axis [10^{-6}mm/mm] measured for longitudinal section of connecting rod body

3. CONCLUSION

By comparing the results for maximum values of normal elastic strain (Z axis) obtained from finite element analysis and measurements using strain gages, we can see small differences. For example the maximum value of normal elastic strain obtained from FEM is $\approx \left| -2{,}667 \cdot 10^{-6} \right|$ [mm/mm] according to conrod longitudinal section studied (see Figure 12) while from measurements it has a maximum value of $\approx \left| -2{,}34 \cdot 10^{-6} \right|$ [mm/mm].
While there are several methods of measuring strain, the most common is with a strain gauge, a device whose electrical resistance varies in proportion to the amount of strain in the device. In practice, the strain measurements rarely involve quantities larger than a few millistrain ($\varepsilon \cdot 10^{-3}$). Therefore, to measure the strain requires accurate measurement of very small changes in resistance. To measure such small changes in resistance, and compensate for the temperature sensitivity, strain gauges are almost always used in a bridge configuration with a voltage or current excitation source. The general Wheatstone bridge, consists of four resistive arms with an excitation voltage, that is applied across the bridge.

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