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POSSIBILITIES OF FORCE MEASURING IN PROFESSIONAL DEFENCE

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Abstract − This article is aimed on finding the best method of measuring a force in professional defence. We chose direct punch for our experiment, because it is a basic defence technique in majority of martial arts. There are many methods for measuring but we decided for strain gauges. In this article we compare two strain gauges and we find the best choice according to function, simplicity of measuring and precision of results.

Keywords: sensor, strain gauge, force, professional defence, punch**.**

1. INTRODUCTION

Force is a physical vector quantity expressing the degree of influence of objects or fields. It manifests with static (causing deformation of object) or dynamic (changing velocity vector) effects. Other quantities such as torque, pressure and acceleration are derived from the force. Currently the methods with transformation to electrical quantities are often used for measurement of the force. This is due to greater accuracy and usually easier to perform measurements. In electrical engineering, it is preferred measurement according to some variable parameters (resistance, inductance, capacitance) and then to add transducers generating voltage, charge or current [1].

In parametric transducer elastic deformation under load is transmitted to the sensor element and causes a change in impedance (resistance and / or reactance), and it is generally is measured by integration into the bridge (Fig.1) [1].

1.1. Strain gauge

Currently, a usual electric strain gauge is a passive electro-technical element used for indirect measurement of mechanical strain on the surface of object according to measure of the object’s deformation.

Relation between material deformation and acting force (in a certain range of forces, it is a direct proportionality) was discovered in 1676 by Robert Hooke and gradually refined to the today’s form of Hooke's law, which is the base of the physical strain gauge measurements.

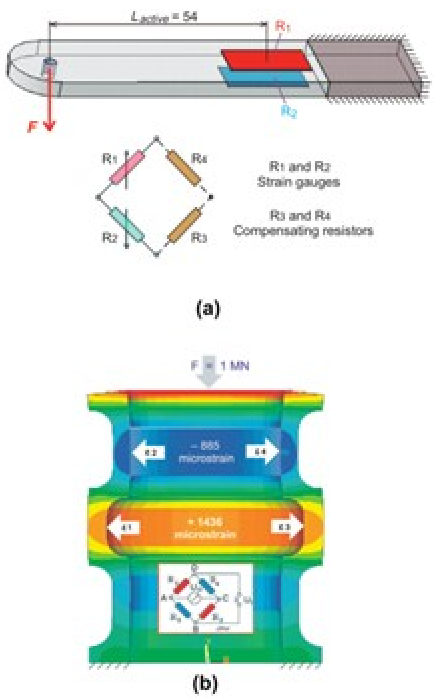

Fig. 1. The Strain Gauges; (a) Foil strain gauges bonded on a cantilever beam (bent lamella). (b) Mechatronic representation of a profiled tube (mechanical structure) designed by FEA (computer program) and sensed by resistive strain gauges, longitudinally bonded on the inner wall of the tube, at the tips of the four white arrows, and connected in Wheatstone bridge (electronic measurement) [1]

Strain gauge belongs to transducers for electrical measurements of non-electrical quantities. Strain gauges are used primarily in two fields as a part of measurement chain (with other necessary devices):

- Analysis of stress of constructional elements (influence of moulded similarities on strength), parts or whole constructions (welds - pressure tanks, vehicle bodies …).
- As a solid integrated part of other device where it is often force as measured quantities (force transducer, scales, …).

Field of study which uses material deformation measurements to study stress is called tensometry.

Previously, mechanical, optical and also acoustic and pneumatic strain gauges were used; however, they were pushed out by electrical strain gauges and the semiconductor resistor, which are passive sensors bonded to the surface of the component (tape strain gauges) or firmly connected with measured object (strain gauges for industrial scales, for continuous monitoring of bridge structures…). It converts mechanical deformation to the change in electrical resistance. The first electrical strain gauges were used around 1938 to study the deformation of locomotive components. They were metal wire strain gauges.

If the wire strain gauge is firmly attached to the surface of the strained object than it has the same deformation as the object. Thus, when stretching it increases its length and reduces the cross-section; according to the material it also changes its electrical resistivity. For metallic strain gauges the electrical resistivity of the material is almost independent of the deformation, i.e. variable ρ is constant. Only dimensions of the conductor affect the change of resistance of metal strain gauge. In the semiconductor strain gauges in which the conductor is for example a silicon strip there is more significant influence of the piezoresistive effect, i.e. the dependence of the resistivity ρ on the mechanical deformation. Properties of semiconductor strain gauges are described in more details in the following table (Table1).

Table 1. Details about semiconductor strain gauges

Material	**silicon**	**silicon**	**germanium**	**germanium**
semiconductor type	Type P	Type N	Type P	Type N
resistivity [-]	0,017-0,02	0,35	1	0,25
resistance (20°C) [Ω]	100-350	100-400	50-500	50-300
the coefficient of strain sensitivity (20°C) [-]	130	-100 to -130	55	-100
working current [mA]	20-40	10.20	10.25	5.35
working range of strains [mm]	$\pm10^{-3}$	$\pm5.10^{-4}$	$\pm5.10^{-4}$	$\pm5.10^{-4}$
Dimensions				
length [mm]	4,4-12,7	5.7	10	3,5-10
thickness [mm]	0,017-0,4	0,1-0,4	0,15-0,5	0,15-0,4
width [mm]	0,05-0,5	0,05-0,8	0,7-2	0,2-2

1.1. Experiment

Our experiment was focused on measuring the profile of direct punch force in time. The main focus was on the differences between genders and among groups of participants with different levels of training. This level was classified according to previous experience in combat sports, martial arts or combat systems.

During direct punch the striking energy (or impulse force) [2] is transferred through arms, particularly through closed fist (Fig. 2). This type of punch is delivered by the arm following direct line.

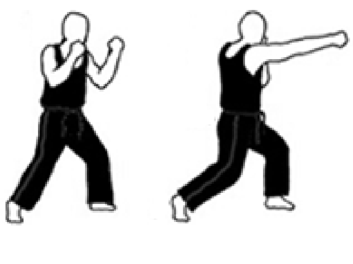

Fig. 2. Direct punch [3]

During the experiment a strain gauge sensor was placed into a leather target (punching bag). The punching bag was subsequently attached to the measuring station created from oriented strand boards (Fig. 3).

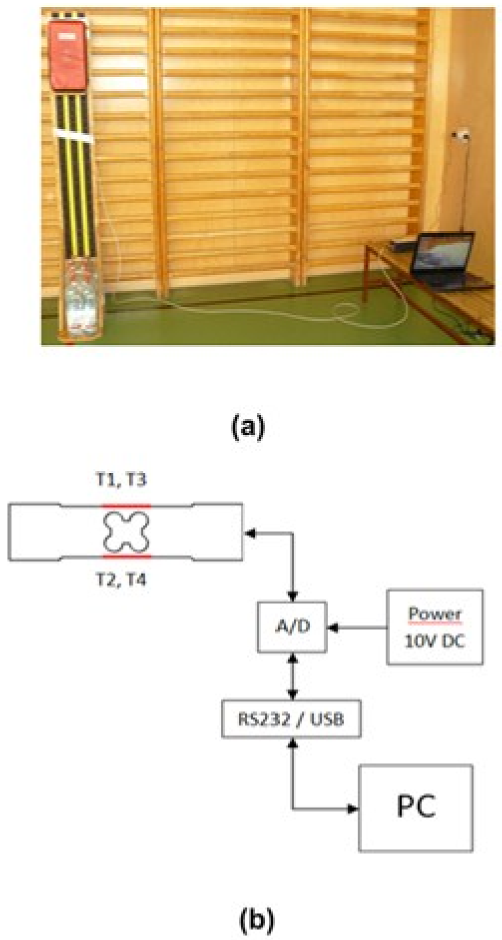

Fig. 3. Measuring station – a) real implementation, b) schematic (for strain gauge type 2) [4]

2. STRAIN GAUGE TYPE 1

The strain gauge sensor [5] of the pressure force, type SRK-3/V (Fig. 4) is a passive electromechanical converter which converts force to a proportional electrical signal [4].

As a mechanical-electrical converter it uses silicon resistive strain gauges because their deformation sensitivity is sixty times higher than that of the film or wire resistive strain gauges. The sensor is sized and calibrated for constant loading of 3 kN force exerted in the axis of the sensor; nevertheless, it also endures a long-term repeated overload up to 200 % (6 kN) in the axis of the sensor [4].

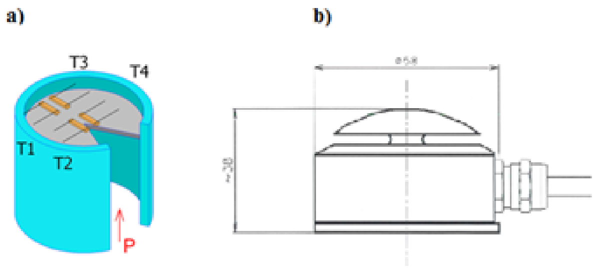

Fig. 4. Pressure force sensor (SRK-3/V) – a) strain gauge placement, b) shape of sensor [4, 5]

The sensor consists of a base in the shape of a short cylinder which turns into a truncated cone in its upper part. The upper base of this truncated cone is formed by a membrane with four silicon resistive strain gauges AP120-3-12 affixed on its inner surface. In the middle of the inner surface of the membrane there is a junctor that connects the membrane to a measuring area in the shape of a spherical cap. All of the described parts of the sensor are made of one piece of dimensionally stable alloy treated steel [4].

The pressure force exerted on the measuring area is being transmitted to the membrane by means of the junctor and deforms it proportionally to any exerted force. At the same time the force is being transferred to four silicon resistive strain gauges fixed to the membrane by a special tensometric adhesive which converts it to an electrical resistance proportional to the deformation. The connection of the strain gauges to the Wheatstone bridge (Fig. 6) provides an effective primary compensation of the influence of temperature on the measuring system [4].

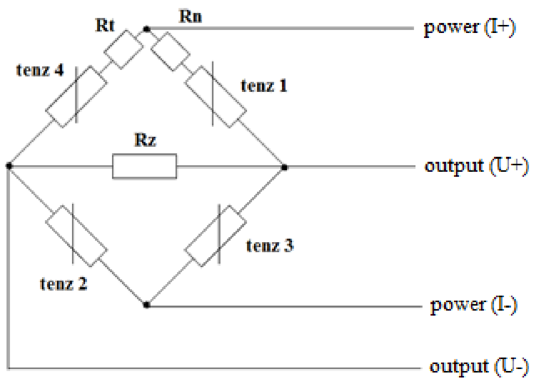

Fig. 5. Wheatstone bridge

Four semiconductor strain gauges are engaged in a Wheatstone bridge. Tenz 1 and tenz 2 are measuring strain gauges which measure the deformation. Tenz 3 and tenz 4 are compensating strain gauges which react to temperature changes. The resistance is experimentally determined at two temperatures. A zero sensor signal is adjusted using the resistor Rn and the output signal is adjusted using resistor Rz.

The sensor is connected to the computer, which is used for data storage, through the strain gauge. The strain gauge type TENZ2334 is an electronic appliance that converts the signals to data that is stored in memory. The core of the appliance is a single-chip microcomputer that controls all of the activities. The strain gauge sensor is connected to this appliance via four-pole connector XLR by four conductors. The number of values measured by the sensor averages around 600 measurements per second while the data is immediately stored in the memory of a device with a capacity of 512 kB [4].

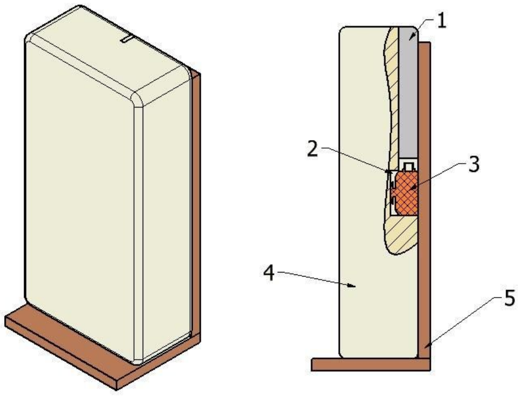

Fig. 6. Strain gauge SRK-3/V in punching bag - 1

1 - cavity for cable
2 - cavity for strain gauge
3 - strain gauge SRK-3/V
4 - punching bag
5 - punching bag base

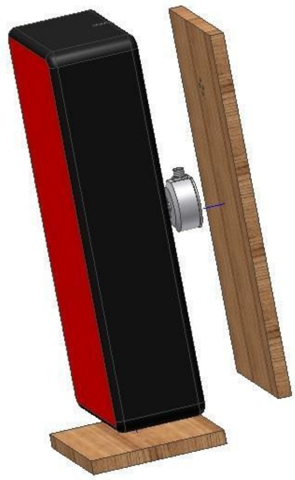

Fig. 7. Tensometric sensor SRK-3/V in punching bag - 2

3. STRAIN GAUGE TYPE 2

The strain gauge sensor L6E-C3-300kg (Fig. 9) works as unilaterally cantilever bending beam. During force delivery the biggest deformation of sensor is in places with the thinnest walls – there are metal film strain gauges which change their electrical resistance depending on deformation. Strain gauges are plugged in Wheatstone bridge and in this way it is possible to convert difference of resistance to electrical signal which we can process [3].

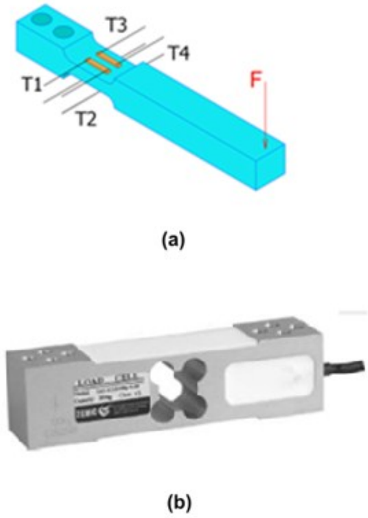

Fig. 8. Strain gauge sensor L6E-C3-300kg – a) strain gauge placement, b) shape of sensor [3, 5]

The sensor is connected to the computer, which is used for data storage, through the strain gauge. The strain gauge type TENZ2334 is an electronic appliance that converts the signals to data that is stored in memory. The core of the appliance is a single-chip microcomputer that controls all of the activities. The strain gauge sensor is connected to this appliance via four-pole connector XLR by four conductors. The number of values measured by the sensor averages around 600 measurements per second while the data is immediately stored in the memory of a device with a capacity of 512 kB [3].

The strain gauge sensor mentioned above was placed on the measuring station according to the following schematic (Fig. 10):

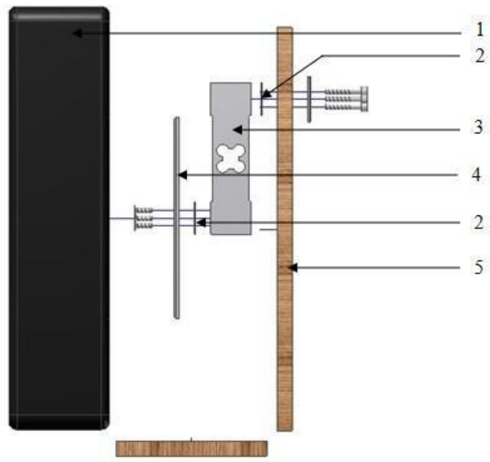

Fig. 9. Measuring station schematic [3]

1 – punching bag (made from hardened vinyl filled with foam)
2 – template
3 – strain gauge sensor L6E-C3-300kg
4 – board (200 x 200 x 5 mm)
5 – punching bag base

4. DISCUSSION

During comparison of these two strain gauges we compared speed of measuring, precision and simplicity of use. We measured around 200 people for each strain gauge. The speed of measuring was 600 samples per second for both.

After evaluating data from strain sensor type SRK-3 / V (type 1) we have seen that this type is unsuitable for measuring. Due to its size it was problematic to act directly on the center of sensor, which is required for correct measurement. This problem was shown at moment when there was big difference between two punches for one person.

This problem is solved in case of second strain gauge (L6E-C3-300kg), because hit area is board in size 200 x 200 x 5mm. Precision of measuring is higher.

5. CONCLUSION

This article was focused on finding the best method for measuring the force in professional defence. We found out the best choice is strain gauge L6E-C3-300kg which has good precision, speed and simplicity of use. In professional defence it is very important to know how strong and effective punch is.

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