COMPARATIVE STUDY OF MECHANICAL AND ELECTRONIC WEIGHING DEVICES. ADVANTAGES AND DISADVANTAGES OF THEIR USE

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Abstract: The paper presents a parallel assesment of electronic and mechanical weighing devices according to a number of criteria such as the possibility of their inclusion in more complex measuring systems, the ability to perform several other functions in addition to the basic weighing function, reliability, cost of acquisition and cost of operation, remote weighing capability and the ability to offset the negative influence of the disturbing, environmental and human factors.The article offers a list of advantages or disadvantages of using the electronic weighing machines, in comparison with the use of mechanical devices, and concludes with a final review of the assesment.

1. THE OPERATING PRINCIPLE

Mechanical weighing instruments are lever type devices serving to determine the mass of bodies by balancing the momentum of the weighted mass with the momentum of a constant mass or a balancing device.
The mechanical balances are devices consisting of a single weighing lever. If they use more levers, only one of them is acting as the weighing lever, while the others' purpose is to transmit or balance the weight forces. Scales may have levers with equal or unequal arms.
Electronic weighing instruments are equipped with electronic measuring modules.
The electronic weighing machines operate based on the following principle: the force exerted by the load situated on the balance pan is transmited to the load cell (one or many) whic in turn emits an electric signal whose intensity is proportional with the force. The electrical signal is picked up by the electronic balance block, processed, amplified and transmitted to a digital display system (digital mass indicator), the result representing the wiught of the mass located on the load pan.
A very common solution is to use strain gauges (strain-sensitive transducers). These are generally used for commercial weighing devices with low resolution.
The strain gauges are wired as a Wheatstone-bridge to compensate for temperature changes. When the system is not loaded all four resistors are the same and the input of the amplifier is zero. When an object is placed on the pan R1 and R4 are compressed and their resistance decreases, R2 and R3 are strained and their resistance is increased. This causes a voltage difference at the input of the amplifier, proportional to the weight of the object.
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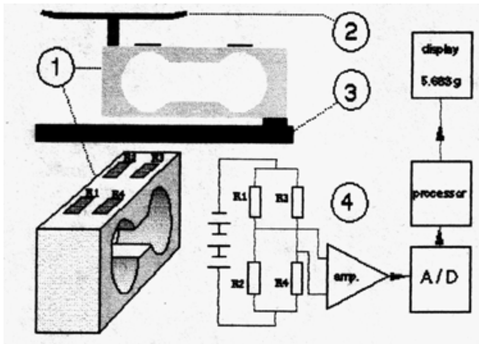


Fig.1 Operational schemes of electronic balances with strain gauges

1 = spring body (side view and in perspective)
2 = weighing pan
3 = mounting plate (housing)
4 = placing and wiring of the strain gauges (R3 and R4 can also be placed on the under side of the beam) [3]

Another constructive solution adopted in the functioning of electronic scales used for commercial purposes is shown in fig.2 and it uses a vibrating string sensor type.

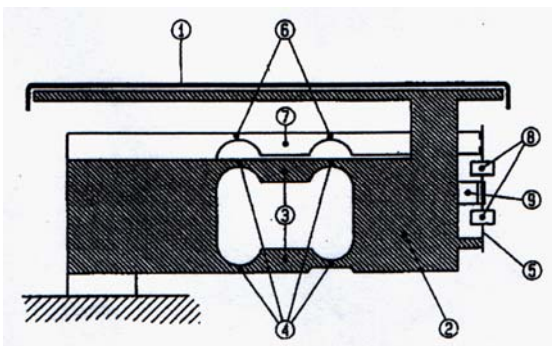


Fig.2 Electronic Balance Sensor type vibrating string

1. Weighing pan
2. Hanger
3. Guide
4. Flexible bearings
5. String (sensor)
6. Flexible bending points
7. Reference string
8. Nodes
9. Permanent magnet

All components are integrated in a mechanical single block of aluminum alloy, called Monoblock.The influence of temperature variations is reduced. The force acting on the load cell is reduced and transferred through the Monoblock system to a vibrating string whose frequency is measured and converted into an electric signal which is the processed its numerical value is displayed on a screen. [1]

2. FIELDS OF USE

Both types of weighing instruments are used in trade, agriculture, laboratories, jewelry, postal services, medical facilities, etc. Thanks to their advanced functions, the electronic weighing devices are used in complex systems for particular purposes such as:

2.1 INTEGRATED WEIGHING AND ADMINISTRATING SYSTEM FOR SHOPS:

Integrated weighing and administrating system for shops:

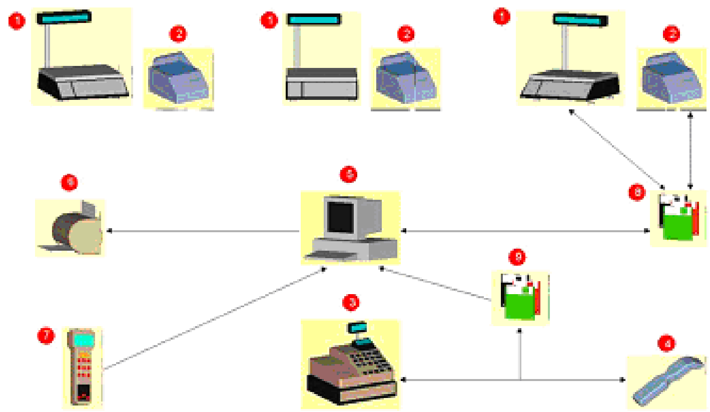


Fig.3 Integrated weighing and administrating system for shops

Usual configuration:

1- weighing posts-realized with electronic scales
2- printers
3- cash register
4- bar cod reader
5- PC
6- printer
8,9-software

2.2 DOSING SYSTEM FOR CO2 GAS CYLINDER WEIGHING

This system allows simultanoueus automatic dosing of CO2 gas in metallic containers (4 cylinders at a time), as well as remote controlling and monitoring of the entire weighing process through a computer (3) using electro-valves (5) actuators.

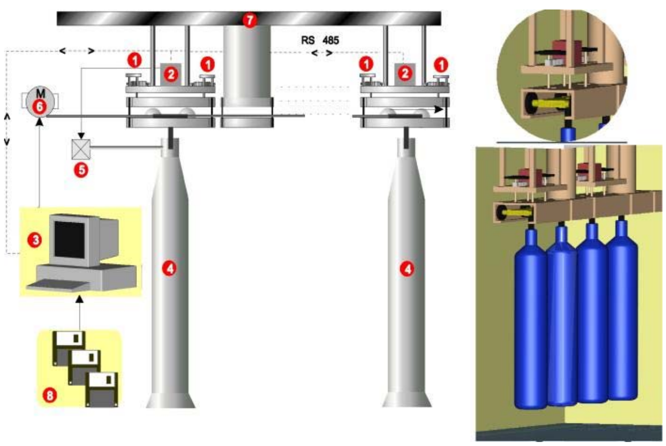


Fig.4 Dosing system through CO2 GAS cylinder weighing

Operating features as it follow :
-bending beam load cells,
-on the gas cylinder suspendet route ; there are anti-shocks and overload limiters
-in the electronic block the weighing is processed during the container stops in the weighing post
-the simultaneously PC controlled movement of the gas cylinders is realized by motor advanced belt
-specific software

2.3 THE WEIGHING AND SIGNALING SYSTEM FOR ELEVATORS

The weighing and signaling system for elevators - used for elevators with acapacity of up to 15 presons, whose task consist of regulating the elevator vertical movement and the stops according to the pre-programmed limits (□people inside the elevator□, □full load□, □overload□). The system including load cells, an electronic block and a portable digital indicator.

2.4 IN-LINE WEIGHING SYSTEM

Is a weighing system dedicated to the applications where the mass is transported on suspendet routes, as in frigorific storehouses, in shambles etc. The weighing is processed statically, when the load rests in any point of weighing sector.
System elements:
- load cells

- digital mass indicator
- suspendet structure
- weighing sector
- load
- PC
- suspendet route [2]

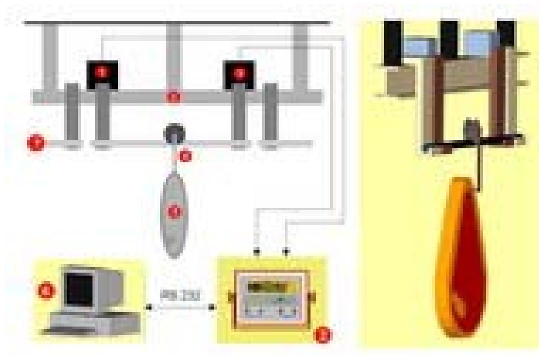


Fig.5 In-line weighing system

3. DISTURBING FACTORS AND THE POSSIBILITY OF OFF-SETTING THEM

Weighing results may be affected by several factors, such as:

- Factors that depend on the weighing procedure: improper conditions, such as failure to level the measuring device, or weighing a load that is out of the weighing device range.

-- Factors that are related to the weighing devices themselves, such as failure to observe the technical conditions imposed by the manufacturer as well as any malfunctions or wear-out of the constructive elements upsetting the technical characteristics of the weighing device ;

- Environmental factors - can lead to large errors especially in the case of high precision weighing instruments. Existing vibrations near the device location can influence the stability of indications, and can even cause them to malfunction, especially in case of very sensitive scales, such as optical-mechanical analytical scales.

Thermal regime can also influence the correctness of instructions. Heat or cold may cause dilatation or contracting of important constructive elements of scales, such as arms levers of scale analytical and scale standard (which often require a strict temperature of 20°C± 2°C in order to operate properly).

- Human factors can influence the weighing results by incorrect reading due to factors such as parallax error or visual inability to distinguish between the index benchmarks.

All these disturbing factors, except for the human factor (which tends to affect the mechanical devices mainly), may influence the operation of both mechanical and electronic weighing devices.

However, some electronic devices are able to detect some of the problems listed above and issue an error messages, in order to determine the human operator to take the necessary actions, or can perform an automatic off-setting of the disturbing environmental factors (such as temperature variation). Others are equiped with a vibrating adapter whose task is to diminish the environmental vibrations.

In high precision weighing devices the forces acting on the weighing sample (magnetic, electrostatic) are interpreted as changes in mass balance.

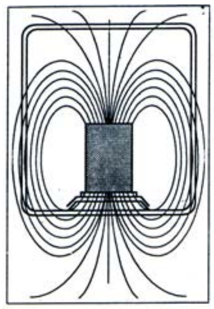


Fig.6 Magnetic weighing samples or containers

The magnetism of a weighing sample can lead to the weighing result being dependent on the position of the weighing sample on the weighing pan. Magnetic forces are interpreted wrongly by the balances as an additional load. In simple cases it may suffice to increase the separation between the weighing sample (aluminium) or glass vessel.

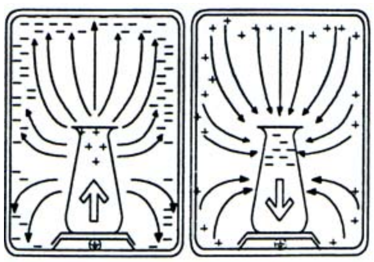


Fig.7 Electrostatic charging of weighing samples and containers

This charging appears in heated rooms with dry air and with weighing samples made of glass or plastic. Electrostatic charging generates forces which can disturb the weighing. This leads to unstable display results. [6]

4. DISPLAY OF WEIGHING RESULTS

Unlike mechanical scales, electronic scales can be used in poorly lit environments (especially those with type LED displays with light-emitting diodes or type VFD-emitting a very bright light and contrast very good).
Another advantage of digital displays is removing reading errors (the parallax error which is possible in analog gauges does not exist in the digital display).
The advantage of reading the analog directions to the mechanical devices compared with electronic balances is to further appreciation of the value indication, where unlike the digital output is made from a digits to a digit.
There are high-precision weighing devices that in their display, displays a symbol of stability detector beside the result of weighing indication. When the symbol is still visible and weighing result is not yet stable, weighing result is displayed in a light shade. Once reached stability, the value displayed gets a more dark color, that can be read easily in this way.
An advantage that electronic scales of precious metals used in jewelry, is to give possibility to adapt digital mass indicator to be showen to the buyer. Instead, in the mechanical display by projection, the indication can be seen only by the seller.

5. ELECTRICAL POWER SUPPLIES

From the point of view of consumption of electricity, electronic devices are disadvantaged compared with the mechanical ones. But there are mechanical devices, such as analytical balances with output made by projection , which require electric power for lighting microscale divided into units of mass.

Using power supply from the A.C. network, electronic stationary scales may be exposed to special situations that can disturb their operation:

- value-change of grounding plug by oxidation of its contacts;
-atmospheric lightning;
-anger caused by cable-rodent

Portable electronic scales , besides the possibility of energy supply from AC outlet they have the possibility to function with batteries. Also, many electronic devices have possibility to reduce energy consumption:

-shows the power saving function (standby)
-low-brightness display automatically when the balance is not used for preset time.

6. FUNCTIONS PERFORMED BY WEIGHING INSTRUMENTS

Generally, mechanical balances can only determine the mass of an object. Some of them are able to assure the Tara function. Besides the basic function, electronic balances may have an impressive number of features such as:

-the possibility of quick reducing of indication errors by internal calibration, external calibration or in automatic mode based on predetermined time and / or temperature criteria, and the recording of the previous calibrations and times at which they were made;
-equipped with interfaces allowing simultaneous connection to multiple peripherals (printer, computer, auxiliary display, barcode reader);
-weighing results can be displayed in different units of measurement;
-automatic opening/closing of doors of the protection building against the current
-possibility of weighing-percentage (Percent Weighing)
-possibility of determining the density of solid objects;
-graphic terminal sensitive to touching (Touch Screen)
-automatic detection of peak load exceeded the weights by a sounds or graphics message alert reducing the risk of destruction of the device by rapid using of the user.

And the list does not stop here!

7. METROLOGYCAL PERFORMANCES

From the point of view of metrologycal performances, both types of weighing instruments are used in a large measuring range, starting with micro-analytical balances with maximum limit of tens of grams weighing capacity and reaching to high capacity scales like a truck scales and railway scales with 100 tonnes weighing capacity or bigger, but sometimes, weighing accuracy is superior for electronical balances (for example:
electronic mass comparators which can reach a 0,1 µg resolution .)

8. RELIABILITY AND OPERATING COSTS

Related to reliability, relative short term, electronic balances are advantages regard mechanical balances, but long-term, the situation can be modified, the problems can be appear to keyboards, displays, load cells etc., necessitated to replacement them and reparation costs much bigger comparative with the mechanicals, where often are necessary only adjusting operations, such as removement the knifes on the stones, adjustment the mirrors (for analytical mechanical balances). Costs to repair of some body parts (such as the change knifes and stones) are less comparative with replacement costs of load cell or another electronic parts.

The working principle of mechanical scales are common, therefore, many of adjustment problems can be resolved by almost authorized laboratory.

They are a large variety of models of electronic balances. Many of body parts are not interchangeably. Even for same producer, there is no substituing a keyboard with another (often they are different related to dimensions), or a load cell with another (with other measurement characteristics such as maximal capacity, measuring range or resolution) becouse are modifying the metrological characteristics, or just like that are not compatible. Each electronic balance model required other calibration programs for eliminated the weighing errors. Each these agents offer possibility to repair electronic balances by lessened number of authorized laboratory.

9. TRANSPORT DISORDER RISK

In the case of transportable balances, the electronical balances show obvious advantages compared with the mechanical ones.

The disorder risks are more at the mechanical scales, like a knifes movement on the pillows, accidentaly breaking of windows for protection (for the semi-automatic balances, loosing oil from damper when they are inclined during the transportation when they have dumper) etc.

Some of the mechanical balances have the opportunity of blocking their weighing mechanism during transportation.

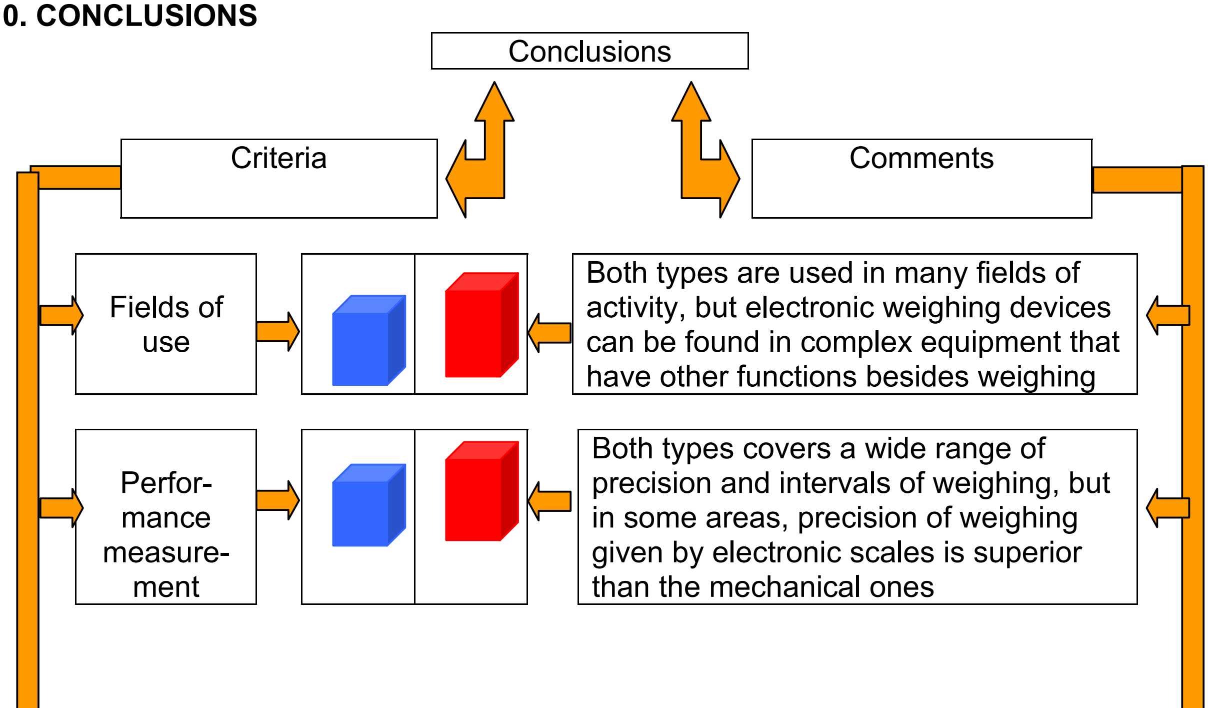
The electronic balances are compact, easier and they can be often transported without problems .

Also, the high capacity mechanical scales, such as truck scales, have the disadvantage that they aren't transportable. But it was made small size portable electronic systems for weighing wheel load.

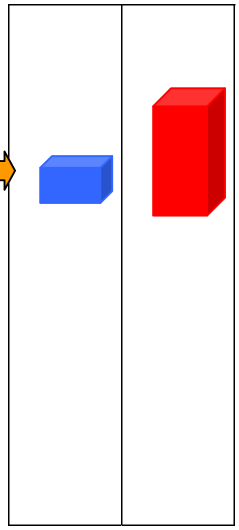
a) b) c)

Fig.8 Models of electronic systems for weighing wheel load

10. CONCLUSIONS

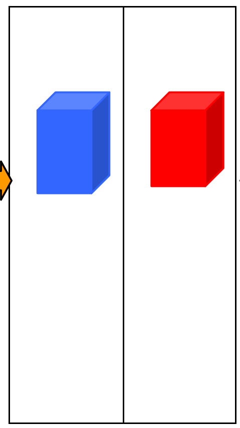


Functions performed by weighing machines



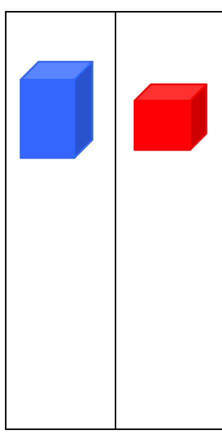
Besides the basic function-weighing, electronic balances can perform a large number of functions. In the sector of direct sales to the population, electronic balances has the undoubtedly advantage of automatically calculating the total price based on unit price. They can be connected to the network and can issue tickets with information about the product weighed. Unlike mechanical devices, some electronic weighing scales for trains and vehicles can be used both as a static and dynamic weighing system, which leads to shortening of weighing time.

Reliability and operating costs



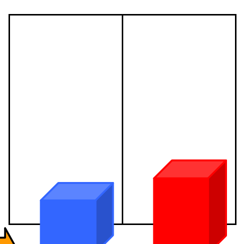
From the point of view of reliability, in the short term, electronic devices are advantaged compared with the mechanical ones, but in the long term, the situation may reverse, repair costs are higher to the electronic balances compared with mechanical ones where adjustment operations are often required. The purchase price is lower in mechanical balances. Operating costs are also lower because of mechanical devices require no electricity costs.

Energy consumption

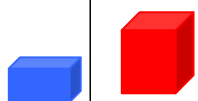
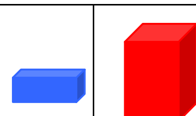


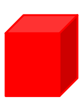
Reported consumption of electricity, electronic devices are disadvantaged compared with the mechanical ones. Also, operating costs are lower because mechanical devices require no electricity costs. Although they are more simple, mechanical devices are a “back up” required for the electronic ones of which may be endangered by accidental stopping of power supply or the influence of intense external electromagnetic fields.

The influence of external factors to the weighing results and



Influencing factors to the weighing results may influence both the mechanical operation of weighing instruments, and electronic ones. However, some electronic devices are able to detect some variations in

offsetting them			environmental factors and to compensate automatically through automatic calibration, and some are equipped with a vibrations adapter designed to reduce their influence if the balance is working in environments with vibrations. Also, some may alert with an error messages of the factors that depend on weighing mode, such as: the use of weighing out or weighing ranges horizontal position failure.
Display of weighing results			Electronic balances can be used in poorly lit environments. The advantage of reading the analog directions is the continous appreciation of the indication values. However, the digital display reading error is removed (from parallax). In some electronic scales used in jewelry is possible to adapt an additional mass-oriented indicator to the buyer side. Instead, in the mechanical balances, that display by projection, the indication can be seen only by the seller.
Transport disorder risk			In the case of the portable weighing devices, the electronic devices shows clear advantages compared with the mechanical ones. Electronic devices are compact, lighter and can often be transported without problems.

	The advantaje (percentage) of using mechanical weighing devices
	The advantaje (percentage) of using electronic weighing devices

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