A Strain Gauge Based System for Measuring Dynamic Loading on a Rotating Shaft

M. Hilal Muftah and S. Mohamed Haris

Abstract— In a mechanical system, the acting mechanical power is the most important quantity of rotating shaft of machines. There are many methods to measure it such as measuring the torque directly on the rotating shaft and measuring the rotational speed. Also there are many widely used measuring methods and more or less standardized instruments for measuring the rotational speed. A digital hand tachometer was chosen for measuring speed. The torque measurement is more complicate than the speed measurement. It needs a special solution in every occasion. It must be built onto the machine’s shaft. This is because the high accuracy, a relatively simple application and the high dynamical behavior, the strain gauge sensor will be chosen for measuring the torque on the rotating shaft. During the design, the shaft was adapted for application of “V shape” strain gauge, to the shaft’s end a HBM made slip-ring assembly was connected the rotating shaft with the standing cable and the Spider8 measurement electronics. The HBM CATMAN-Express software was used during the calibration and the tests. The calibration was carried out with 0.5 m long lever and dead weights in 0.5 kg steps up to 4.5 kg.

Keywords—HBM CATMAN-Express software, mechanical power, slip-ring assembly, strain gauges.

I. INTRODUCTION

THOUGH torque is unquestionably an important mechanical quantity in the field of machine building; its significance is not confined to that area alone. The precise measurement of torque, particularly that which occurs in rotating components, places heavy demands on manufacturers and users of tests benches. The situation is further complicated by the trend towards improving the mechanical performance of modern engines by increasing their speed of revolution; couple with a desire for greater accuracy in such areas as the measurement of efficiency [2].

This challenge is met by continuous development taking into account the ongoing advances in the application fields. Whilst torque shafts according to the original design principle are still used for certain applications, the full range of transducers now includes torque measurement hubs and torque flanges. Innovations in contact less torque transducers concern the transfer of power from the stator to the rotor and the transmission of measurement signals [9]-[16].

The strain gauge has been in use for many years and is the fundamental sensing element for many types of sensors, including pressure sensors, load cells, torque sensors, position sensors, etc[1]-[4].

The majority of strain gauges are foil types, available in a wide choice of shapes and sizes to suit a variety of applications. They consist of a pattern of resistive foil which is mounted on a backing material. They operate on the principle that as the foil is subjected to stress, the resistance of the foil changes in a defined way [3].

In a mechanical system, the acting mechanical power is the most important quantity of rotating shaft of machines. There are many methods to measure the acting mechanical power, such as measuring the torque directly on the rotating shaft and measuring the rotational speed. The torque measurement is more complicate than the speed measurement. It needs a special solution in every occasion. It must be built onto the shaft. This is because the high accuracy, a relatively simple application and the high dynamical behavior, the strain gauge is used for measuring the torque on the rotating shaft [3]-[5].

Torque is the key quantity in all investigations and refinement operations, particularly for the development of internal combustion engines and transmissions since, in combination with rotation speed; it provides the possibility to calculate mechanical power [11].

Whereas at one time, particularly in the case of engine test benches, this measuring task was fulfilled by the use of braking devices with a measurement capability, nowadays the trend is toward in-line torque measurement with the aid of rotating torque transducers. The main reasons for this are that the processes are always dynamic and the interplay between mechanisms such as the engine and the transmission are becoming an increasingly important consideration when they come to optimization [12].

Torque is defined as measure of how much force acting on an object causes that object to rotate. The object rotates about an axis, which is called “Pivot Point (O)” and “Force (F)’”. The “Distance (r)” from the pivot point to the point where the force acts is called the moment arm. Note that this “Distance (r)”, is also a vector, and points from the axis of rotation to the point where the force acts, as shown in “Fig.1,” [1]-[7]-[8].

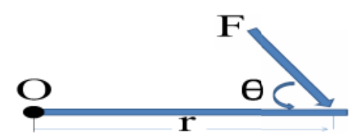

Fig.1. Force acts

More generally, the torque on a particle (which has the “Position (r)” in some reference frame) can be defined as the cross product:

$$\tau = r * F \quad (1)$$

Where “particle's position (r) “is the vector relative to the fulcrum, and “Force (F)” is the force acting on the particle. The “Magnitude (τ)” of the torque is given by:

$$\tau = r * F * \sin(\theta) \quad (2)$$

Where "Distance (r)" is the distance from the axis of rotation to the particle, " Force (F)" is the magnitude of the force applied, and "Angle (θ)" is the angle between the position and force vectors [16]-[17]-[18].

Mechanical power in mechanics, the work done on an object is related to the forces acting on it. To calculate the mechanical power the formula as shown below can be applied:

$$P = M \cdot \omega \quad (3)$$

II. Materials and Methods

A. Torque measurement methods

1. Reaction force at the end of a lever.
2. Determination from the electrical performance.
3. Deformation of a shafting element modification of:
   - 3.1 Capacity.
   - 3.2 Inductance.
   - 3.3 Resistance.
   - 3.4 Permeability.
   - 3.5 Phase relation.
4. Hydraulic measuring shafts.
5. Pneumatic solution.

Reaction torque is the torque required to prevent the stator of a rotary device from turning with the rotor (e.g., the housing of a generator from rotating with the driven rotor).

It can be measured by mounting the housing on bearing so that it is free to rotate, and then attaching a lever arm (reaction arm) to the housing and connecting a force transducer between the end of that arm and mechanical ground, the surface to which the outer portion of the bearing is attached [3].

B. Strain gauge

Although the undisputed success of torque measurement using sophisticated instrument, strain gauges are still commonly use in the industries due to its simplicity and its relatively inexpensive price. Strain gauges also offer a high degree of accuracy when measuring the torsion that metal is subjected to when a torque is applied [2].

A strain gauge, in mechanical term, is a device for measuring mechanical strain. However, in instrumental term, it is generally taken to mean the electrical resistance strain gauge, and as the name implies, the strain gauge is an electrical conductor whose resistance varies in proportion to the amount of strain in the device. It is thus transducer, whereby strain is converted into change of electrical resistance [2]. Selecting the appropriate type of strain gauges for the torque transducer is a very important task as the correct type of strain gauge chosen will optimize the gauge performance and give accurate and reliable strain measurement [8].

The main selection criteria for strain gauges are:

1. Gauge length.
2. Grid geometry.
3. Grid resistance.

The functioning of a strain gage, contrary to most other types of extensometers the strain gage delivers the relative quantity "strain (ε)" as an output signal proportional to the input and not as the "differential (Δl)" of a reselected base "length (l)". The functioning of metallic strain gauges is basically a strain effect on the resistance of electrical conductors, which was first discovered in 1843 by Wheatstone and systematically researched by Thomson in 1856 [2]-[3].

The "resistance (R)" of an electrical conductor changes with a "ratio (ΔR/R)" if is stressed mechanically in such a manner that its length changes by a "factor (Δl/l)".

The change in resistance depends partly on the change of the geometry of the conductor, and partly on a change of the specific "conductivity (ρ)" of the conductor material due to changes of the material structure texture [2].

The strain gauge must be mounted on the surface of the specimen of which the stress shall be determined. This is done with the aid of special cements, although special techniques for mounting the specific type of gauge are required. E.g. high temperatures may require ceramic cements, spot-welding, or flame-spraying [3].

Direct embedding of the gauges is used in model structure analysis and in structural concrete analysis which makes it possible to measure stress inside a structure for a three-dimensional strain analysis [2]-[14].

The strain gauges change resistance in response to the surface strains they sense. The relationship between strain and resistance is expressed by the "gauge factor (K)" of the strain gage foil, which can range from 2.0 to 4.0. The most common foil in constantan, a 55% copper, 45% nickel alloy with a gauge factor of 2.0 [21].

We can say that the measured value of the strain gauge, the relative change of the "resistance (ΔR/R)", is proportional to the "strain (ε)" with the "factor (K)":

$$\frac{\Delta R}{R} = \varepsilon . \kappa \quad (4)$$

Additional circuitry and instruments are needed to further process for the measured value of strain gage. A suitable combination is called "measurement chain" and might contain different elements depending on the measurement task on hand.

C. Measurement using strain gauge

Most torque transducers use strain gage transduction, some use reductive transduction, and some of relatively recently developed design use the difference in angular displacement between the two ends of a torsion bar to obtain either a phase-difference measurement or a variable illumination measurement. For the special case of torque measurement there are available gauges with two grids at plus and minus 45 degrees with reference to the axis of symmetry [1].

D. Strain measurements and stress analysis for various loading cases

The elementary loading cases "normal" (tensile, compressive loading), "bending" and "torsion" occur very seldom, if at all, in a pure form. Usually the loading cases are superimposed to some extent whether this is desired or not. In the following subsections the options for the determination of pure or combined loadings are discussed. The arrangements of the strain gages on the object and within the Wheatstone bridge play a significant role here.

Explanation of the formula symbols used in the research:

SG 1 ….SG 4 = temperature compensated strain gages for compensation for thermal expansion

E = modulus of elasticity

F = force

G = shear modulus

$R_1 \ldots R_4$ = position of the resistances within the bridge circuit

R_c = completion resistances for making up the bridge circuit

ε_i = indicated strain value

ε_n = normal strain (tensile or compressive)

ν = poisson's ratio

σ = material stress

σ_l = stress in the longitudinal direction of the measurement object

σ_n = normal stress

σ_u = stress on the upper side of the measurement object

σ_{lo} = stress on the underside of the measurement object

ω = angular frequency

E. Measurement on a tension/compression bar

With a tension bar the "positive longitudinal stain (ε_l)"occurs in the active direction of the force, i.e. the longitudinal direction; in the transverse direction the negative transverse strain, i.e. "transverse contraction (ε_t)" occurs. With a compression bar the longitudinal strain is negative and the transverse strain is positive. The following relationship applies for the "longitudinal strain (ε_l)"

$$\varepsilon_l = \frac{F}{A \cdot E} \tag{5}$$

With a pure normal force $\varepsilon_l = \sigma_n$

For the transverse strain ε_t

$$\varepsilon_t = -\,\nu \cdot \varepsilon_l = -\,\nu \frac{F}{A \cdot E} \tag{6}$$

The normal stress σ_n is given by the following relationship

$$\sigma_n = \frac{F}{A} \tag{7}$$

Or

$$\sigma_n = \sigma_n \cdot E \tag{8}$$

F. Measurements on a shaft under torsion (twisted shaft)

A measurement on a twisted shaft can have several objectives:

1. *The determination of the normal and the shear stresses for stability considerations.*

A shaft loaded with torsion is subject to a biaxial stress state. The principal normal stresses occur at an angle of $\pm 45^0$ to the cylindrical planes (lines running parallel to the longitudinal axis of the shaft). The strains are produced by the normal stresses which can be measured with strain gages [7]. The "V shape" with the measuring grid axes at $\pm 45^0$ to the axis of symmetry will be used. A correct result will only be given by a correct measurement. The axes of the measuring grids must correspond to the principal stress directions. Deviations by the angle α give a measurement error e of:

$$e = (\cos 2\alpha - 1) * 100\% \tag{9}$$

If a strain gage is mounted with a directional error of ($\alpha = 5^0$), the measured value will be (1.6%) too small. With half and full bridge configurations, if the other strain gages are correctly oriented, then the error is reduced to (-0.8%) for the half bridge configuration and to (-0.4%) for the full bridge configuration.

It should be noted, however, that with unsymmetrical arrangements of strain gages larger errors can occur due to improper compensation of any existing normal and bending strains. Suitable configurations are the half and full bridge circuits. With the transmission of measurement signals from rotating shafts through slip-rings the full bridge circuit must be used, otherwise changing contact resistances within the bridge circuit can cause significant measurement error. With the full bridge circuit the contact resistances in supply leads 2 and 3 are in series with the bridge resistance and in the measurement leads 1 and 4 they are in series with the amplifier input impedance [7].

The full bridge configuration is also the best in compensating interference signals from superimposed normal and bending loading, the principal normal "stresses (σ_1) and (σ_2)" can be calculated from the measured "strains (ε_1) and (ε_2)" Stress state with known principal directions; they are given below:

$$\sigma_1 = \frac{E}{1-\nu^2}(\varepsilon_1 + \nu \cdot \varepsilon_2) \tag{10}$$

$$\sigma_2 = \frac{E}{1-\nu^2}(\varepsilon_2 + \nu \cdot \varepsilon_1) \tag{11}$$

The following applies to the twisted shaft:

$$|\varepsilon_1| = |\varepsilon_2| \tag{12}$$

$$\varepsilon_2 = -\varepsilon_1 \tag{13}$$

If the strain gages are wired as a half bridge in the bridge arms 1 and 2, then a change of sign occurs for (ε_2), the "indicated strain value (ε_i)" then becomes:

$$\varepsilon_i = \varepsilon_1 - (-\varepsilon_2) = |\varepsilon_1| + |\varepsilon_2| = 2\varepsilon \tag{14}$$

A corresponding result is obtained for the full bridge circuit.

Hence there is a change of in the expression within brackets in the following equation compared to equations (10) and (11).

For the half bridge circuit:

$$\sigma_{1,2} = \pm\frac{1}{2} \cdot \frac{E}{1-\nu^2} \cdot (1-\nu) \cdot \varepsilon_i \tag{15}$$

For the full bridge circuit:

$$\sigma_{1,2} = \pm\frac{1}{4} \cdot \frac{E}{1-\nu^2} \cdot (1-\nu) \cdot \varepsilon_i \tag{16}$$

The "shear stress (τ)" increases from (τ = 0) at the center to the maximum value (τ_{max}) at the circumference.

$$\tau_{max} = 2\,\varepsilon_{45^0} \cdot G \tag{17}$$

$= \varepsilon_i \cdot G$ For the half bridge circuit,

$= \frac{1}{2}\ \varepsilon_i \cdot G$ For the full bridge circuit

ε_i = indicated strain value for the full and half bridge circuits

G = shear modulus

2. *The determination of the effective torsion moment M_t from which the transmitted power P can be calculated for a rotating shaft.*

The torsion moment M_t can be calculated from the "shear stress (τ_{max})" which is determined according to equation (17) and from the "polar section modulus (S_p)"of the shaft as follows:

$$M_t = \tau_{max} \cdot S_p = 2\, \varepsilon_{45}{}^{0} \cdot G \cdot S_p \quad (18)$$

For the half bridge circuit:

$$M_t = \varepsilon_i \cdot G \cdot S_p \quad (19)$$

For the full bridge circuit:

$$M_t = \frac{1}{2}\, \varepsilon_i \cdot G \cdot S_p \quad (20)$$

Where (τ) and (G) in N/cm^2 and (S_p) in cm^3 (M_t) is given in N.cm. The "polar section modulus (S_p)" is dependent on the cross-sectional shape of the twisted shaft. Formulae for its calculation are given in the appropriate literature.

For a cylindrical shaft the following applies:

$$S_p = \frac{\pi \cdot d^3}{16} \approx 0.2d^3 \quad (21)$$

The "power (P)" transferred from the rotating shaft is calculated as:

$$P = \omega \cdot M_t = \frac{2\pi \cdot n}{60} \cdot M_t = 0.105 \cdot n \cdot M_t = \frac{n \cdot M_t}{9.55} \quad (22)$$

Where (M_t) in Nm, the "speed (n)" in min^{-1} and (P) is obtained in Nm/s = W.

3. *The deter urination of the shear deformation angle γ or of the twist angle Φ.*

The shear deformation angle is calculated as

$$\gamma = \frac{\tau_{max}}{G} \quad (23)$$

And the angle of twist as

$$\varphi = 2 \cdot \frac{\iota}{d} \cdot \gamma = 4\varepsilon_{45^\circ} \cdot \frac{\iota}{d} \quad (24)$$

For the half bridge

$$\varphi = 2\varepsilon_i \cdot \frac{\iota}{d} \quad (25)$$

For the full bridge

$$\varphi = \varepsilon_i \cdot \frac{\iota}{d} \quad (26)$$

III. Results and Discussion

A. *Strain Measurement Circuit*

The resistance changes in strain gauges are converted into voltage changes by passive network. The voltage is then amplified for signal transmission or display [11]-[18]-[20].

Excitation is supplied to such networks from regulated power supply. The output of networks used with semiconductor strain gauges may be large enough, for some applications to obviate the need for amplification [2] [16].

Wheatstone bridge circuits are used for all most types of the strain measurements.

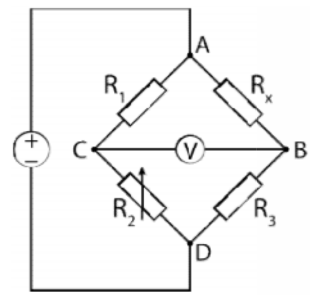

Fig.2. Wheatstone bridge circuit four active arms

The most commonly used, Wheatstone bridge circuit is used as a strain gauge bridge, it is four active arm bridges, in which each one of the four arms is active, which means that each arm contains a gauge that senses strain.

B. *The Torque Transducer with Strain Gauge*

Strain gauge installation, strain gauges differ from most other sensing devices in that their installation intended to be permanent, they cannot be removed and reused. Proper installation is, therefore, essential. The following are generally the major steps in procedures for bonding strain gauges by means of an adhesive [1]:

1. Surface preparation: The surface to which the gauge is to be bonded must be cleaned completely and should be roughened slightly; this is best done immediately before gauge installation.

2. Adhesive application: The proper adhesive must first be selected, adhesives can be of the solvent-release type, contact-setting type, epoxy, phenolic, polyimide, or for high temperature application, ceramic cements.

3. Clamping and curing: Most installations require clamping of the installed gage, using a metal plate with a strip of non adhesive plastic between gauges and applying pressure to the plate.

4. Moisture-proofing.: After curing and removal of clamping devices, a moisture-proofing compound should be applied over the installed gauge.

The electrical connections between the gauge leads and system cabling are frequently made by affixing small insulated terminals to the measured surface near the gauge.

Such terminals can be welded to the surface, or they can be attached by an adhesive, in which case their installation is part of the gauge installation.

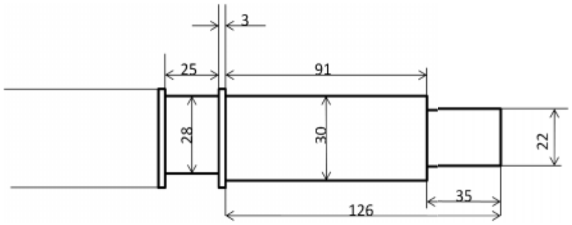

Fig.3. Shaft with 28mm in diameter

Fig.4. Spider8 measurement electronics

The indicated strain value can be calculated with using the following data:

"Electrical Power (5KW)", with "Torsion Moment (22.08Nm)", "Diameter (28mm)" of shaft, "Speed ($3000min^{-1}$)", "Young's Modulus ($202KN/mm^2$)"and "Poison's Ratio (ν=0.28)" [6]-[16].

Then the calculation can be applied as following:

For full bridge circuit (four active strain gauge)

$$\varepsilon_i = \frac{2M_t}{G \cdot S_p} \tag{27}$$

Where:-

$$G = \frac{E}{2} \cdot \frac{1}{1+\nu} = \frac{E}{2(1+\nu)} = \frac{202}{2(1+0.28)} = 79\ kN/mm^2 \tag{28}$$

$$S_p = \frac{\pi d^3}{16} = 0.2d^3 = 0.2(28)^3 = 4390\ mm^3 \tag{29}$$

$$\varepsilon_i = \frac{2M_t}{G \cdot S_p} = \frac{2*22.08*1000N.mm}{79*\frac{1000N}{mm^2}*4390mm^3} = 0.127 = 127\ \mu S \tag{30}$$

The strain of a single strain gauge:

$$\varepsilon = \frac{\varepsilon_i}{4} = \frac{127}{4} = 32\ \ \mu S \tag{31}$$

C. Torque Transducer Calibration

There are various methods of transferring the measuring signal from rotating shafts. For a slow rate of rotation with only a few revolutions of the measuring object, a cable that winds and unwinds provides the simplest solution. It is applicable to all types of circuit [15]-[17].

A second method is the transfer of the bridge supply voltage and the measuring signal using sets of slip rings. Only high quality versions are suitable due to the requirements for extremely low contact resistance between the slip ring and the brush. Low wear at high speeds and very low thermal voltages are also demanded [6]-[19]-[20].

The calibration has been done with Spider8 setup, the output of the "Voltage (mV/V)" has been taken from the computer for each weight, increasing and decreasing the weights in Spider8 channel set up windows in Ch0 the full bridge must be selected, with zero load the tare function has been done in "Voltage (mV/V)", all the results have been organized in tables.

HBM supplies this type of equipment as slipping assemblies for fitting to rotating shafts of various sizes with two sets of brushes for separate mounting. The set contains five slip rings; four for connection of the strain gages and the fifth providing a ground connection with the rotating shaft to prevent interference. Slip ring assemblies for mounting on the free end of a shaft can be supplied with 6 slip rings [11]-[12]-[13].

Measurement signal transmission via slip rings, the voltage supply and measurement signal in HBM torque measuring shafts are transmitted over hard silver slip rings and silver graphite carbon brushes. The combination offers optimum interference-free signal transmission (low noise, low thermally-induced voltages), log service life ($3 \times 10^8 \ldots 6 \times 10^8$ revs) and therefore minimal maintenance effort [11]-[12].

Two sets of brushes are used in order to guarantee reliable contact in all operating conditions. The two sets are arranged so that two brushes are held by spring pressure against each slip ring, but offset at a certain angle. Although four slip rings are actually enough for signal transmission, HBM torque shafts are fitted with a fifth slip ring to equalize the potential between the rotor and the stator. Perfect equalization is generally not guaranteed via the bearings. Without this potential equalization considerable signal interference can result from differences in potential [11]-[12].

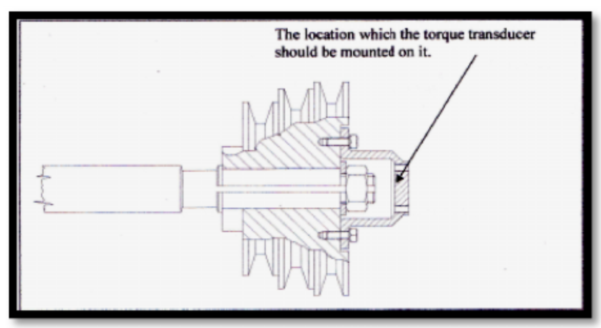

Fig5. Shows the location of the torque transducer

D. Choosing Strain Gauge Units

All the information about the strain gauge which they are needed is indicated:

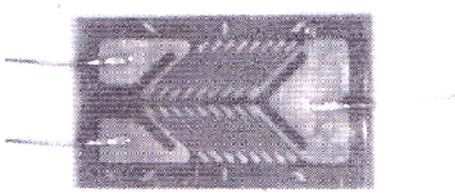

Fig6. “V shape” strain gauges

Gauge length = 2mm, Gauge factor = 2.05±1%
Gauge resistance = 120Ω ± 0.4.

Although better contact materials a certain amount of variation of the contact resistance (contact noise) is unavoidable with slip ring transmitters.

HBM states a contact resistance between the slip ring and the brush of “40 m Ω” with variations of” < 2mΩ”. Whereas the contact resistance itself is relatively unimportant, variations in its value are reproduced in the measuring signal. And the torque transducer has been connected to the device of Spider8 which has been connected to the computer [12]-[13].

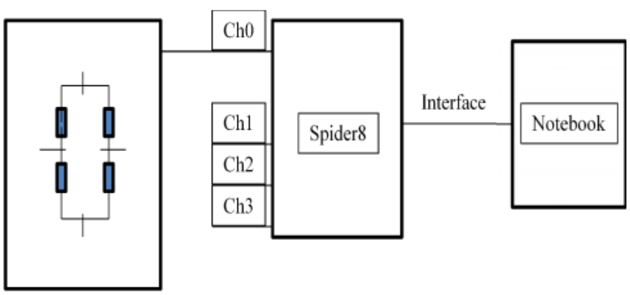

Fig7. Schematic of the torque transducer and its connections

To calculate the torque, first and foremost strain gauge has to be measured, to do this measuring weights to be needed, in this case difference weights have been used, which they respectively are “0.5, 1, 1.5, 2, 2.5, 3, 3.5, 4 and 4.5 kg”.

Weights have to be converted from “Kilogram (Kg)” to” Newton (N)” as following:
“Force (N)” = “mass (kg)” * “9.81(m/s^2)” $= 0.5kg * 9.81\frac{m}{s^2} \ldots N = 4.905\ N$

Torque is calculated using the following formula:

$$M = F * l \qquad (32)$$

$$= 4.905N * 0.5m = 2.4525Nm$$

Where:
F = “Force (N)”
l = “Length of the Lever (m)”.
Then “Torque (Nm)”.

The data have been taken three times which they’ve been divided into three series. The average of the three series will be calculated then we will fill the results in following table.

m[kg]	F[N]	M[Nm]	Average mV/V
0.0	0.00	0.00	
0.5	4.91	2.45	
1.0	9.81	4.91	
1.5	14.72	7.36	
2.0	19.62	9.81	
2.5	24.53	12.26	
3.0	29.43	14.72	
3.5	34.34	17.17	
4.0	39.24	19.62	
4.5	44.15	22.07	

Table.1. the total average of the three series

After that the “Strain ($\mu\varepsilon$)” for each resistance also will be calculated from table.1 at torque M in Nm.
As known mV/V = $2000\mu S$

It will be compared to the indicated strain which calculated in section (31). The transducer will be tested during operation in real condition, measurement of the electrical power and speed. In the Lab the grinder will be connected to the electrical operation, all the connections instrumentation for current and voltage and Spider8 device will be connected to computer to get the results.

First step testing will be calibrated without load; the results will be measured three times to be ready for the next step.

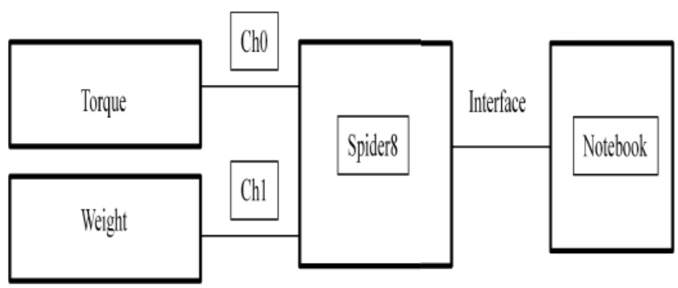

Fig8. Schematic for the measuring of torque and weight

Testing the transducer during operation within loads (4kg) of the corn will be used for real conditions to measure the mechanical power and the speed.

The calibration value of “Torque (Nm)”, “Voltage (V)” between two phases, the line “Current (A)”, the “Electrical Power (W)” and the “Speed (rpm)” which it will be measured with special device, (Tachometer) will be used to read the speed during operation it sends a ray directly to small piece which will be mounted on the bearing to receive the reading of the speed [14].

To calculate the mechanical power the formula as shown below can be applied:
Where n in rpm

$$\omega = \frac{2\pi}{T} = 2\pi * f = 2\pi\frac{n}{60} \qquad (33)$$

Then to calculate the mechanical power we will use the formula in section (3).

E. Setting Catman®Express Software:

The software associated with computer-controlled measuring equipment determines whether the system function is user-friendly. The software is an integral component with many tasks to perform, affecting every aspect of the measurement process.

In I/O input and output channel window, channel names and detected channels are displayed, therefore the properties torque, weight and time can be chosen. The setup and units also appeared in this window and another window to inter the bridge and gauge factors can be done, bridge factor is (4), gauge factor is (2.05).

The setup assistant window displays in the Ch0 full bridge torque hand, Ch1 full bridge against load.

In the two windows the “Torque value (Nm)” against the “Strain value (mV/V)” is displayed. Also “Weight (kg)” against the “Strain value (mV/V)” is displayed.

IV. Conclusion

Though torque is unquestionably an important mechanical quantity in the field of machine building, its significance is not confined to that area alone. In a mechanical system, the acting mechanical power is the most important quantity of rotating shaft of machines. It can be calculated from the torque and the shaft speed. Several kinds of torque measuring methods were presented. There are many widely used measuring methods and more or less standardized instruments for measuring the rotational speed. A digital hand tachometer was chosen for measuring speed.

The torque measurement is more complicate than the speed measurement. It needs a special solution in every occasion. It must be built onto the machine’s shaft. This is because the high accuracy, a relatively simple application and the high dynamical behavior, the strain gauge sensor was chosen for measuring the torque on the rotating shaft. During the design the shaft was adapted for application of “V shape” strain gauge, to the shaft’s end a HBM made slip-ring assembly was connected the rotating shaft with the standing cable and the Spider8 measurement electronics. The HBM CATMAN-Express software was used during the calibration and the tests. The calibration was carried out with (0.5 m) long lever and dead weights in (0.5 kg) steps up to (4.5 kg). The linearity error the hysteresis errors will be noted. Also the sensitivity of the transducer will be calculated and will be compared to the “normal” torque transducer (2.0mV/V) because we don’t want to alter the stress strain properties of the original hammer grinder very much. The whole measuring system from strain gauge sensor through the Spider8 up to the PC is capable measuring with high dynamics. The difference of the calculated and measured strain will be compared.

The tests will be carried out with real conditions. Three series of measurement will be done. (4 Kg) of corn will be grinded every occasion. The torque and the increase of the output material will be measured versus time with (10 Hz) sampling frequency. The rotational speed will be measured by digital tachometer. Electrical power will be measured with portable electrical power meter. The real mechanical power will be calculated after test. Also the Microsoft Office Excel will be used for data processing and visualization.

The grinder in the laboratory supplied with this up-to-date measuring system gives the better possibility for analyzing the whole mechanical process.

Acknowledgment

This work is supported by the People’s Bureau of the Great Socialist People’s Libyan Arab Jamahiriya, Kuala Lumpur, Malaysia and Faculty of Engineering & Built Environment Universiti Kebangsaan Malaysia 43600 UKM Bangi, Malaysia and they are gratefully acknowledged.

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