APEM journal **Advances in Production Engineering & Management** 7 (2012) 2, 93-100
ISSN 1854-6250 Professional paper
http://dx.doi.org/10.14743/apem2012.2.133

CONCEPTION OF UNIVERSAL EXTENSOMETRIC CUTTING DYNAMOMETER

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Abstract:
This paper presents and describes the design, manufacturing, calibration and performance of a universal cutting dynamometer based on the principle of extensometer strain gage techniques. The device developed in this paper was designed and calibrated for measuring separately components forces developed during turning, drilling and milling operations. Its design is carried out according to the two principal criteria which are in contradictory matters such as sensitivity and rigidity.

It consists principally of two circular rings, one allowing its fixation on the tables of the three type of machine tools, and the other one is machined so that the complete dynamometer can be attached to machines tables. The strain gages are then cemented on the parts of the dynamometer where the deformations (traction, compression and torsion) are maximum. The gages are connected in the form of a full wheatstone bridge, any unbalance in which would indicate the thrust force ant the torque providing maximum sensitivity and complete temperature compensation.

The disposition and the connection of the strain gages in complete Wheastone bridge are carried out according to the force component to measure while taking account of the interactions between the three directions and the compensation of the effect of the temperature. The reading is indicated on standard indicator of constraints B & K 1526. Some experimental measurements of components forces and torque in the drilling process obtained with the described dynamometer are presented and compared with available data given by other research worker.

Key Words: Cutting Forces, Dynamometer, Extensometer Strain Gages, Wheatstone Bridge, Wiring

1. INTRODUCTION

The knowledge of cutting forces is one of the basic objectives of metal cutting. It is then necessary for a rational design and dimensioning of the machine tool parts and optimum choose of cutting tool. It is also needed to prevent tool wear and occurrence of chatter vibration which affect the cutting accuracy and surface finish, and also provide some information on the machinability of the material. These constraints resulting from the cut bring the production engineer to acquire a profound knowledge in machining and linking the technology to the economic context.

In this paper, we propose to design a universal cutting dynamometer based on the technique of extensometric strain gages allowing a direct lecture of the three force components and their moments encountered on the main conventional machining processes such as turning, milling and drilling.

The conception of this monobloc dynamometer is fairly simple and is based upon two main contradictory conditions: the sensitivity and rigidity. It consists essentially of two circular discs, one for attachment to tables of machine tools, and one must allow the fixation of the tool or work piece holder as the case used. Both crowns forms studied are linked together by a thin-walled hollow cylinder on which we must stick sixteen (16) strain gages; eight (08) gages are cemented along a vertical axis parallel to the cylinder and the other eight (08) along a position angle of 45 ° relative to the generators of the cylinder, and having the same direction. To obtain a sensitive installation, these gages must cemented at points in the cylinder where the deformations (tensile, compression and torsion) that appear are the greatest.

The reading is shown on indicator strain type B & K 1526 The arrangement and connection of the strain gages in full bridge Wheatstone are realised according to the component to be measured taking into account interactions between the three forces components and the compensation of the effect of temperature. The performance of the dynamometer was tested after calibration during drilling operation, and the measuring cutting force and axial torque are compared with available data given by other research worker [1].

The stress distribution subjected to the cylinder during machining is determined by the principle of Mohr's circle.

Gage I1 is applied to traction, then the resistance R (I1) increases, and I5 to compression, so its resistance R (I5) decreases. The connection of strain gages I1 and I5 is as shown in Figure 1.

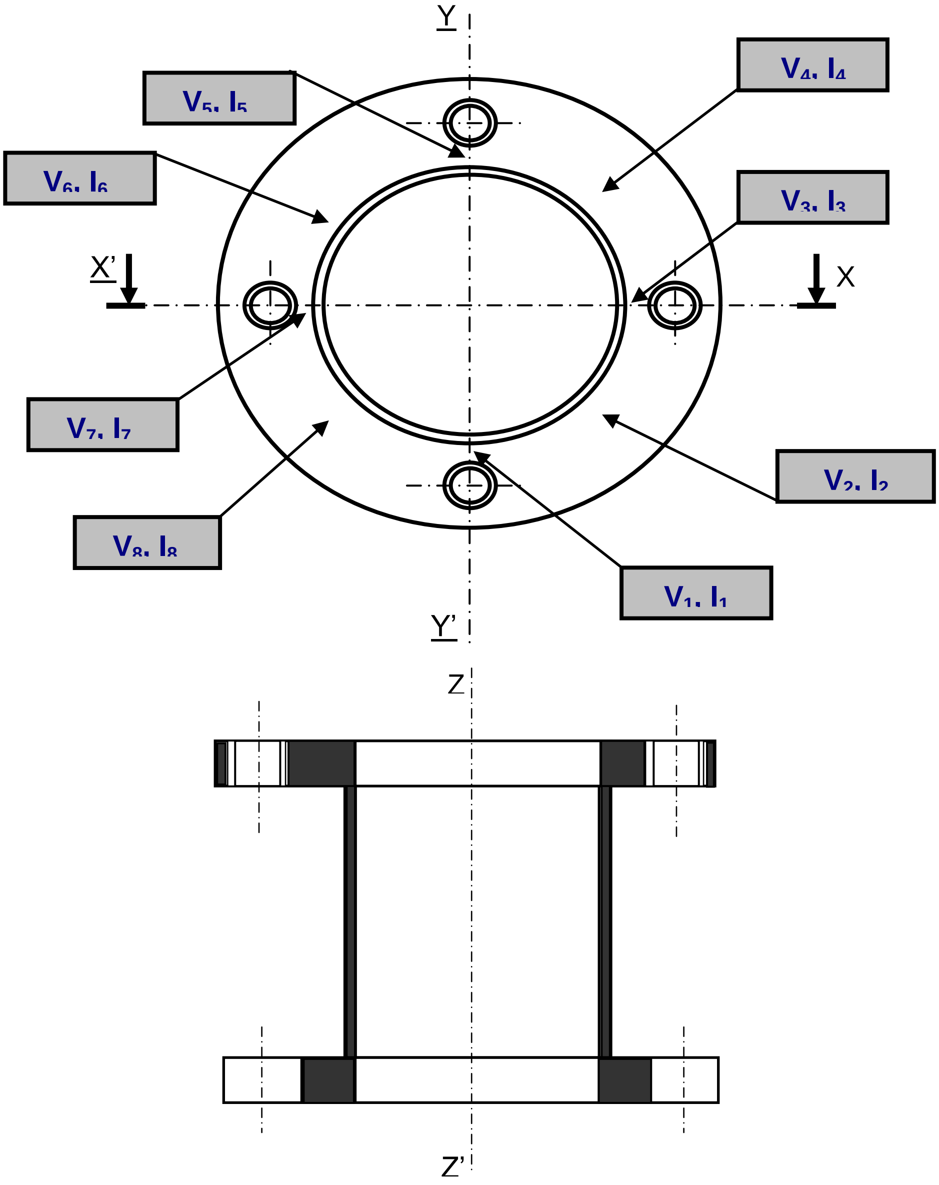

Figure 1: Design of the dynamometer.

2. STRAIN GAGES WIRING

2.1 Measuring Fx

When the resistance R (I1) increases, the voltage which appears in S2 is lower than E / 2. When the resistance R (I5) decreases, the voltage that appears in S1 is greater than E / 2.

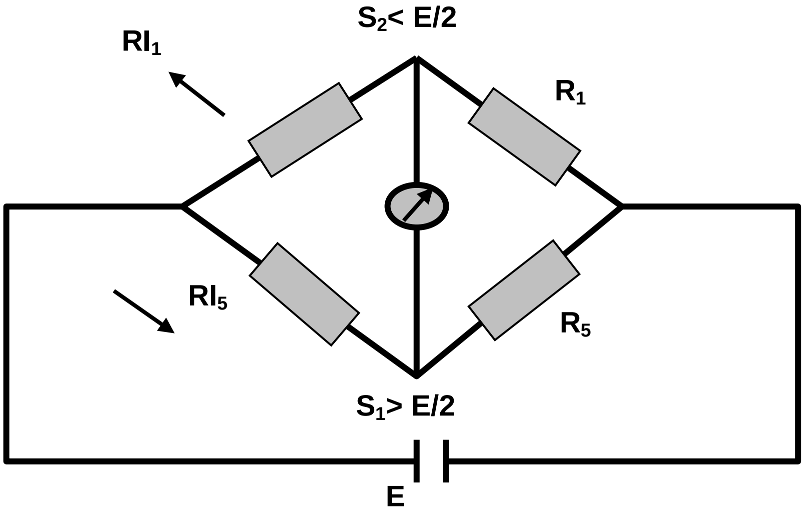

Figure 2: Wiring for the measurement of Fx.

2.2 Measuring Fy

I7 gauge is applied to traction, or an increase in the resistance R (I7), and I3 to compression, so its resistance R (I3) decreases. The connection of gauges I3 and I7 is the same way as for the FX component as shown in Figure 3.

When the resistance R (I7) increases, the voltage that appears in S1 is less than E / 2.

When the resistance R (I3) decreases, the voltage that appears in S2 is greater than E / 2.

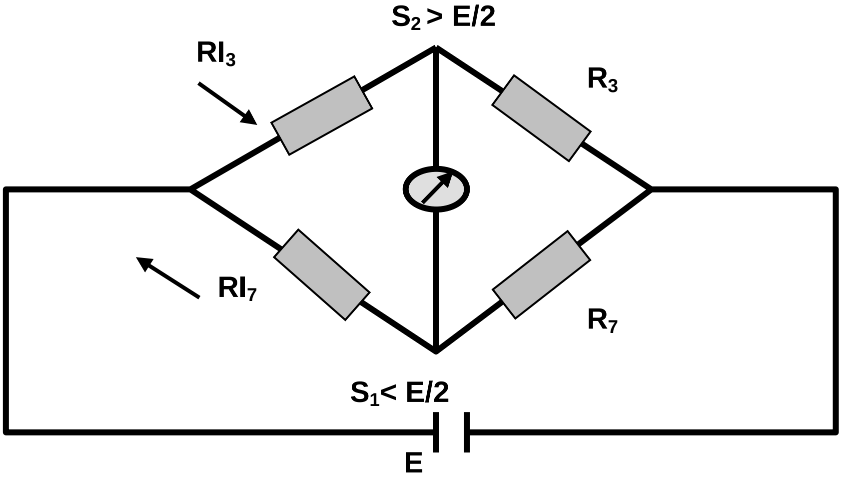

Figure 3: Wiring for the measurement of Fy.

2.3 Measuring Fz

In this case strain gages V2, V4, V6 and V8 are all subjected to compression, so that a change in voltage across the bridge, the gages are connected as shown in Figure 4.

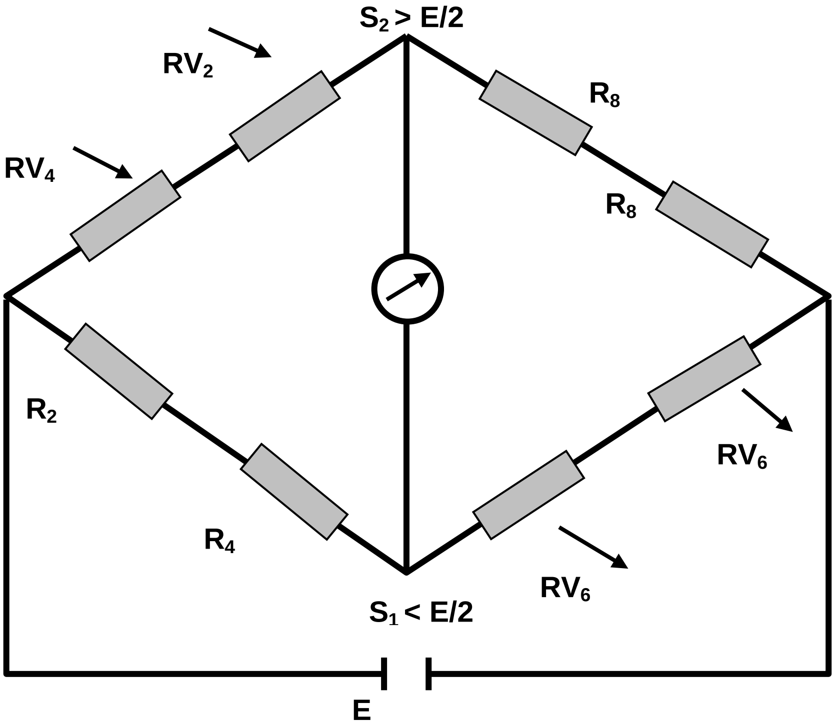

Figure 4: Wiring for the measurement of the moment Fz.

2.4 Interaction of other directions

2.4.1 Interactions of Fx

When the system is stressed by the axial component Fx, strain gages V2 and V4 are subjected to tension and gages V6 and V8 to compression. The voltage across S2 is greater than E / 2 for the resistance R (V2) and R (V4) increase, and the voltage across S1 is less than E / 2 for the resistance R (V6) and R (V8) decrease, so there is compensation in each arm of the bridge, in this case it is in equilibrium, and the interaction of Fx is assured.

2.4.2 Interactions of Fy

When the system is stressed by the axial component Fy, strain gages V4 and V6 are subjected to tension and gages V2 and V8 to compression. Therefore there is compensation in each arm of the bridge, it is then in equilibrium, and the interaction of Fy is also ensured.

2.4.3 Interactions of Mxx, Myy and Mzz

The interaction of moments M_{XX} M_{yy} is similar to those of forces components Fy and Fx, respectively. The action of the moment MZZ strain gages V2, V4, V6 and V8 are subjected to the same strain, the bridge is in equilibrium, and the interaction is also assured.

2.5 Measuring Mxx

Strain gages V1 and V5 are used to measure the moment M_{XX}. Strain gage V5 is subjected to a traction, the resistance R (V5) increases, and V1 to compression, so its resistance R (V1) decreases. The connection of these strain gages is shown in Figure 5.

When the resistance R (V5) increases, the voltage that appears in S1 is less than E / 2. When the resistance R (V1) decreases, the voltage that appears in S2 is greater than E / 2.

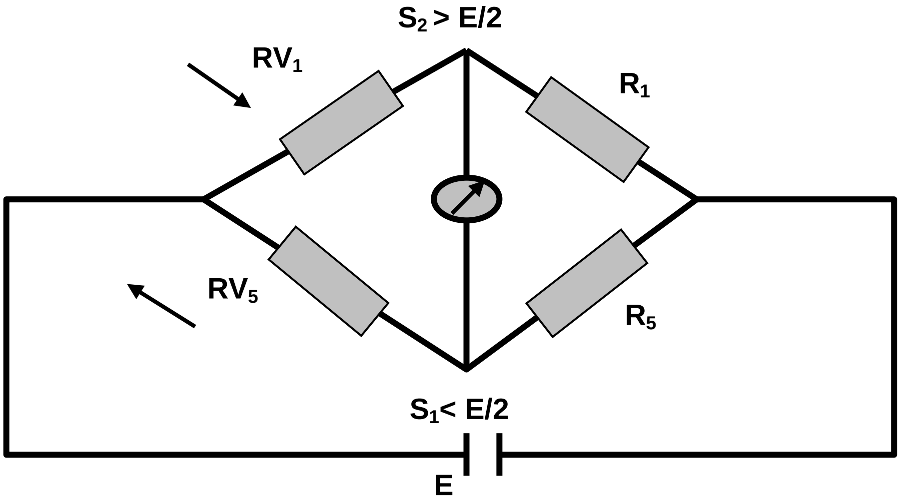

Figure 5: Wiring for the measurement of moment Mxx.

2.6 Measuring Myy

Strain gages V3 and V7 are used to measure the moment Myy. Strain gage V3 is subjected to a traction, its resistance R (V3) increases, and V7 to compression, so its resistance R (V7) decreases. The connection of these strain gages is shown in Figure 6.

When the resistance R (V3) increases, the voltage that appears in S1 is lower than E / 2.

If the resistance R (S7) reduces the voltage that appears at S2 is greater than E / 2.

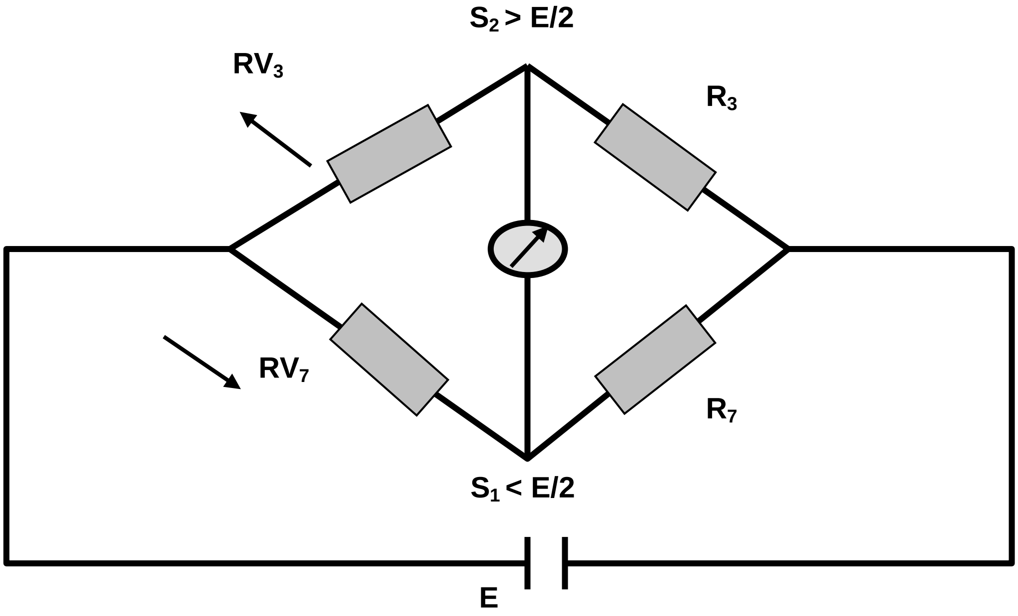

Figure 6: Wiring for the measurement of moment Myy.

2.7 Measuring Mzz

Strain gages I1, I4, I6 and I8 are subjected to the same strain (tension), so their resistances R (I2), R (I4), R (I6) and R (I8) increases. The connection of these strain gages is identical to the circuit of Figure 6.

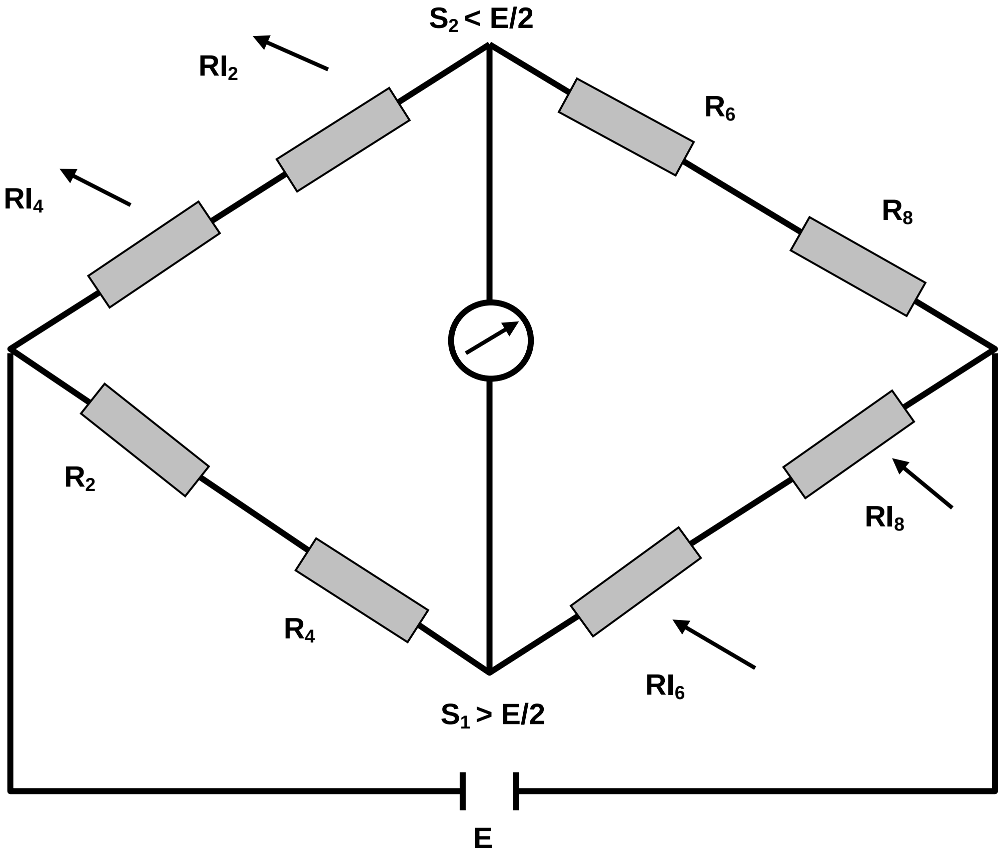

Figure 7: Wiring for the measurement of moment Mzz.

3. EXPERIMENTAL TESTING

Test conditions:
Workpiece material: X75NiCrMo533
Material of drill: A.R.S
Point angle: 118 °
Helix angle: 30.

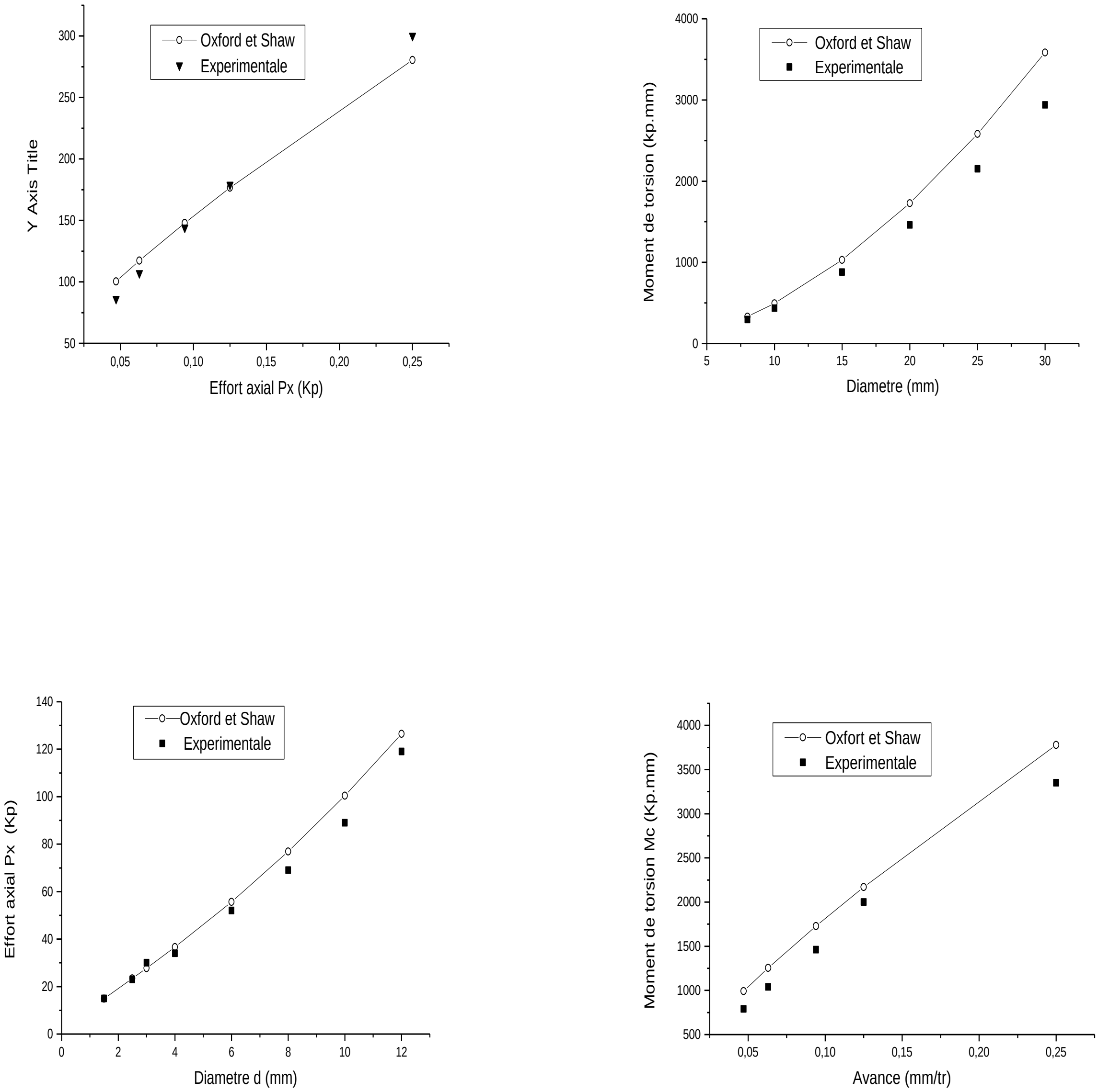

Figure 8: Curves experiments.

4. CONCLUSION

After calibration of the described dynamometer, its performance has been evaluated through experimental tests. All drilling tests has been conducted on a workpiece with previously drilled pilot hole of about one forth (¼) of drill diameter, the conclusions that can be drawn are:

1. The dynamometer is of simple design, robust and is suitable for use in drilling operation;
2. Its calibration characteristic is fairly linear with varying thrust force and torque;
3. The experimental results closely agree with the theoretical results and those obtained by research workers in the field (Shaw et oxford).

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