LABORATORY UNIT TO TEST THE PERFORMANCE OF ELECTRIC MOTOR

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ABSTRACT

Electric motors are widely used in the agricultural industry, yet many researcher and students in Egypt need to understand their basic operating characteristics. Designed laboratory activities can provide an accepted method for students under Egyptian conditions to observe and actively study motor operation. However, commercially available electric motor test are prohibitively expensive for many agricultural systems of technology at the University level. The aim of the current study was to develop the construction and evaluation of an inexpensive unit test for electric motor that allows students to actively study the power output, efficiency, and power factor of small, fractional horsepower AC and DC electric motors. Prony brake laboratory unit test may be easy to measure and determine the power efficiency and power factor for AC motors. The power efficiency was 91% for N3-70 AC motor comparing with 87.3% , 83.7 % and 70.3 % for DC motor KAG, DC motor MNB and AC motor turbo respectively.

Keywords: *power factor, electric motor, performance, unit test*

INTRODUCTION

Agriculture is a major consumer of electricity. According to Nadel et al. (2002), electric motors provide more than 80% of all non-vehicular shaft power and consume over 60% of the electrical energy generated in the U.S. Schumacher et al. (2002) found that unit leaders in university agricultural systems management programs perceived that electricity/electronics was the most important subject matter area for future curriculum emphasis. According to Gustafson (1988), all agriculture majors should receive instruction in electricity. Roth and Field (1991) indicated that students should develop a basic understanding of electric motor selection and operating characteristics.

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Johnson (1993) indicated that the effective instructional programs in electricity must provide students with active, hands-on learning experiences. Slocombe et al. (1990) described manual and computer-based motor test stations for studying electric motor performance. The total cost for the manual motor test station was estimated at $3500, while the computer-based test station was approximately $7500. As well as, the Students have indicated that using the testing stations aids significantly in their understanding of efficiency and power factor. In Egypt there are no available unit tests for the electric motor for students in the agriculture.

OBJECTIVES

The aim of this current paper was developed a related easy method to describe the construction and evaluation of an inexpensive the performance of electric motor in laboratory for students.

MATERIALS AND METHODS

Unit test of electric motor

The unit test consists of the Aluminum frame and the facilities that used to measure the performance of the AC and DC electric motor. The aluminum frame was constructed and used to fix an electric motor. The dimension of the constructed frame was 450 mm x 450 mm. It included the bar that used to fix the weight scalar. The 450 mm tape length was fixed at top and bottom of the aluminum frame to measure the arm of the torque. The brake was made from the PM material and the arm made from the stainless steel as shown in the fig. 1. A commercial quality 0 - 20-kg spring scale (graduated in 300 g. increments) is suspended from the upright by the Teflon coil. The 70 Watt AC motor thermal cut off model N3-70 with 230 V , AC Turbo QB60 with 0.37 kW (0.5 hp) motor and two DC motor KAG model 12 V and NMB model 12 V are attached to a base of Teflon coil 50 mm diameter and 20 mm thickness which turn and secured to the Prony Brake. The arm of torque made from steel and fixed with around coil attached to the test motor and the other free end hung to the spring scale. The load on the motor is varied by increasing and decreasing the voltage input to the different electric motors. Torque is the product of the force in kg read from the spring scale and the length of arm in cm. The variable resistor switch was used to obtain the required voltage and ampere as a very essay control unit of the DC electric motor. The four different electric motors were tested under different loads. The two Hold Peak HP model 760C digital multi-meters and one PSGI digital wattmeter are used to measure the electrical characteristics of the motor circuit as shown in figure 4. As well as, the two multi-meter used to measure the voltage and the Ampere for different motor. The digital Tachometer (Voltkraft TD-01) Laser is used to measure the rotational speed for different DC motors and AC motor.

Procedures and tests

By measuring the mechanical output of a motor and the electrical input to the motor under different load conditions, data can be developed to show the characteristics of the motor. The mechanical output can be measured either with a dynamometer or Prony Brake test apparatus. A voltmeter, an ammeter, and a wattmeter are necessary to measure electrical input. A schematic of a simple Prony brake test apparatus is shown in fig. 2. The Prony brake uses a frictional load against a drum driven by the motor shaft. With this apparatus, the torque created by the frictional force against the drum can be measured and controlled. From the Prony brake test, torque and horsepower can be calculated. Torque is the length of the lever arm L times the force F. Power or work per unit time can be calculated from the torque and revolutionary speed as following:

$$Power = \frac{Work}{Time} = \frac{Forc \quad Dis\tan ce}{Time} = Fx2\pi LxN, kW ......(1)$$

In units of horsepower, output power is expressed as

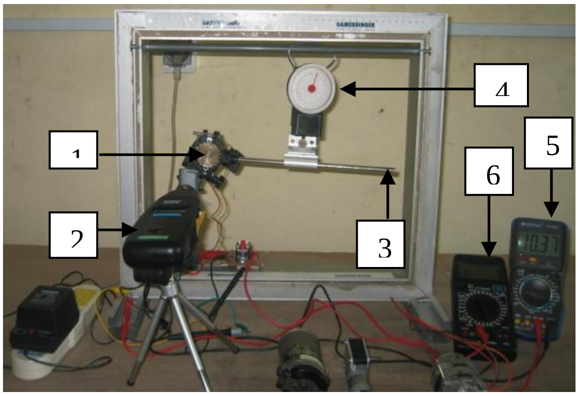
$$Power = \frac{2\pi FLN}{60000}, kW ......(2)$$

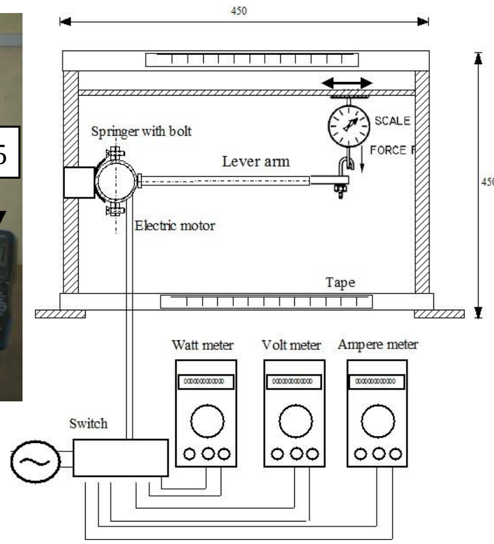
where

F = force, N

L = lever arm, m

N = rotational speed of shaft, RPM





1- Electric motor 2-Tachometer
3- Arm with coil brake
4- Spring Balance 5-Volt meter
6- Ampere meter

Fig. 2: Indicate the Prony brake apparatus

Fig. 3: The arm in Prony brake (a) and (b) the AC N3-70 motor: 1 speed controller 2 and PSGI wattmeter 3.

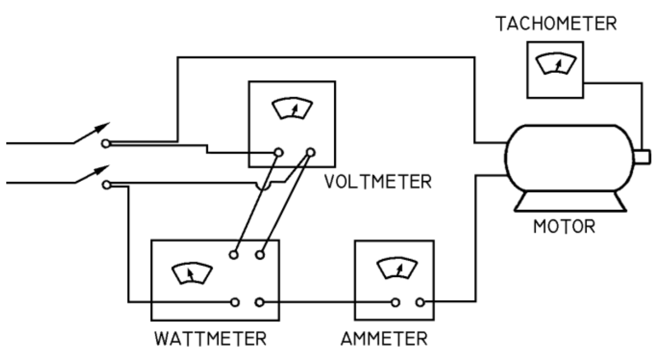


Fig. 3: The electrical instrumentation for measurement of power input to a single phase motor

The instrumentation as shown in fig. 3 used in conjunction with the Prony brake, factors such as efficiency and power factor can also be calculated at any load condition. True input power is measured by the wattmeter.

Motor efficiency

Motor efficiency is the ratio of output power as measured by the Prony brake to the input power as measured by the wattmeter.

$$Motor \quad efficiency = \frac{Power \quad out}{Power \quad in} x100, \qquad \% ....(3)$$

Apparent power can be calculated from the product of current and voltage measurements. Therefore, power factor can be determined from the ratio of true to apparent power, or

$$Power \quad factor = \frac{True \quad Power}{Apparent \quad power} = \frac{Wattmeter \quad reading}{Volts. \quad Ampers} ....(4)$$

An electric motor converts electrical power into mechanical power. Efficiency is the ratio of the mechanical power produced by the motor compared to the electrical power used by the motor equation 3.

When an AC electrical circuit contains an inductive load (such as a motor), a counter voltage is induced into the load coils as the magnetic field surrounding the coil collapses during each AC cycle. The induced counter-voltage opposes the normal change in direction of current flow in the circuit, resulting in a phase shift between voltage and current. The net result is that the current lags the voltage in the circuit. Power factor is the cosine of the phase angle between circuit voltage and current and may take on any value from 0 to 1. As indicated, power factor can be easily calculated as the cosine of the phase angle. However, in many cases the phase angle is not known and no convenient method of measuring it is available. Fortunately, power factor can also be calculated as the ratio of true power to apparent power in a circuit. True power is measured directly with a wattmeter, while apparent power is the product of voltage and amperage, measured with a voltmeter and an ammeter, respectively Srivastava et., al. (1993). In order to be useful as an instructional tool, the Prony Brake must produce results that are repeatable. To assess repeatability, the Prony Brake was used to evaluate the power output, efficiency, and power factor of AC Turbo QB60 with 0.37 kW (0.5 hp) motor and 70 W swing machine AC electric motor model NS-70 . The speed controller model KD-2902 used to obtain the different rotational speed at different loads. Three test replications were conducted, with the applied load ranging from no-load to the last increment before locked-rotor 14.7 N (1.5 kg) in 4.9 N (0.5 kg) increments, and the results were analyzed across each load setting.

RESULTS AND DISCUSSIONS

The results of the current research presented that it may able to measure and test the low electric power of AC and DC electrical motor under Egyptian laboratory conditions. The current research described an inexpensive Prony Brake and instrumentation that can use to evaluate the performance characteristics of fractional horsepower AC and DC electric motors. Students can gain valuable insight into the operating characteristics of electric motors through such activities. The Prony Brake is simple to construct and the necessary instrumentation is commonly available in agricultural systems under Egyptian conditions. Figures 4 and 5 indicated the relation between the rotational speed, the power efficiency and power factor for DC and AC electrical motors under laboratory conditions at different operating load. The increasing of the rotational speed tends to increase of the power factor and power efficiency.

It's able to use the manufactured electrical unit test to measure the power efficiency for AC motor. As well as, it may able to study the effect of some parameters such as rotational speed on the efficiency of electrical motors as shown in figures 4 and 5 at different load. The power efficiency and power factor of the AC motors recorded the high values compared to the DC motor. The values of the power efficiency and power factor were for AC and DC motor at maximum operating rotational speed as shown in figures 4 and 5. The students may be able to measure and test the electrical DC and AC motor to know the performance of the electrical motor that applied in agricultural machine. Table 1 showed that the measuring data from Prony brake for DC motor KAG and MNB under different load conditions. Table 1 may able to indicate the relation between the different items in the equation that the students could understand it. As well as, table 2 listed that the measuring data for true electric power and apparent power in a circuit under different load conditions. The power factor and power efficiency may able to measure for AC motor directly without calculating the angle electric phase. The angle of electric phase of AC motor sometime it is difficult to measure it under Egyptian conditions. Some researchers go to assume it. The above mentioned method (Prony brake laboratory unit test) may be easy to measure and determine the power efficiency and power factor for AC motors. The AC motor N3-70 recorded that the highest value of power efficiency compared to the AC motor turbo, DC motor KAG and MNB model.

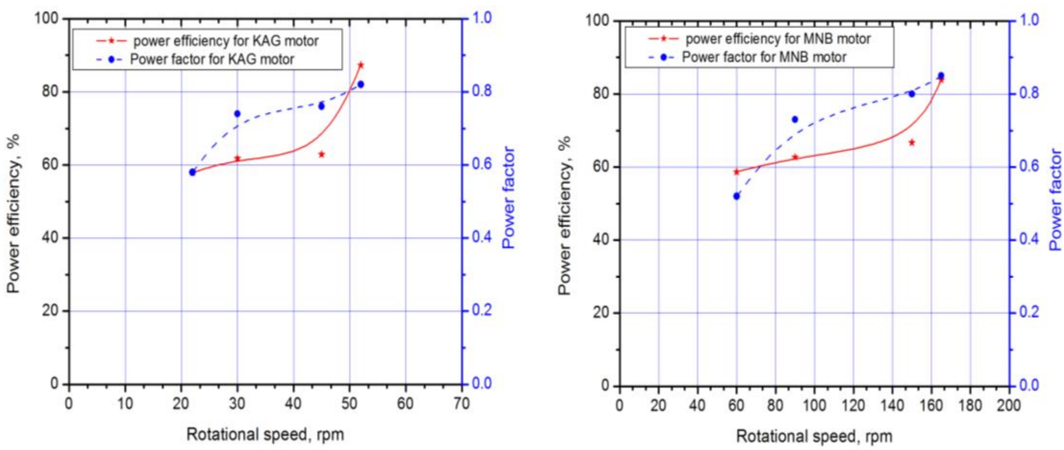


Fig. 4: The power efficiency and power factor for DC motor KAG and MNB at different rotational speed

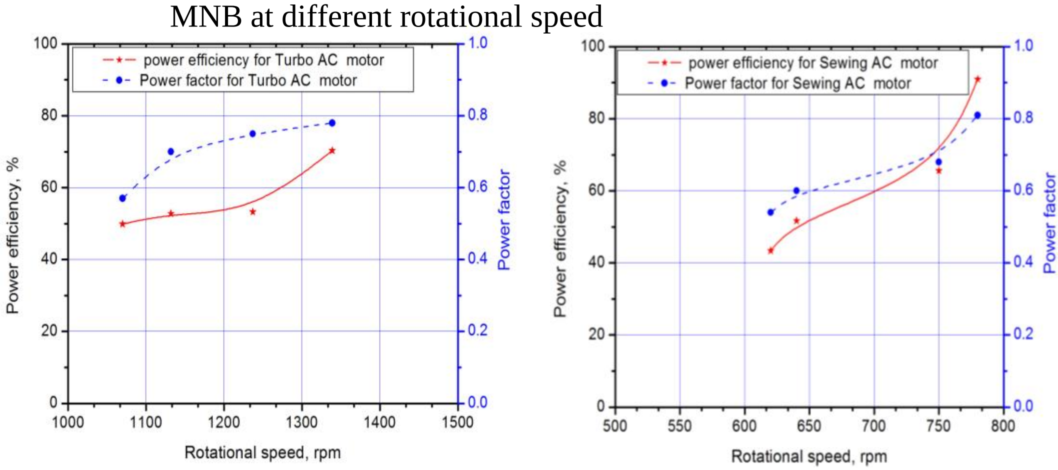


Fig. 5: The power efficiency and power factor for AC motor Turbo QB60 and NS-70 at different rotational speed

The power efficiency were 91% for N3-70 AC motor comparing with 87.3% , 83.7 % and 70.3 % for DC motor KAG, DC motor MNB and AC motor turbo, respectively. As well as the highest value of power factor was found for DC motor MNB. The power factor were 0.85 for DC motor MNB comparing with 0.82, 0.81 and 0.78 for DC motor KAG, AC motor N3-70 and AC motor turbo, respectively.

Table 1: The measuring values of the brake power, power efficiency and power factor for DC electric motor KAG and MNB

DC motor	Force, N	Arm Length, cm	Rotational speed, rpm	Volt in V	Volt out V	Current in, A	Current out, A	Brake Power, w	Elec. power, W	Power effeciency %	Power factor
KAG	4.9	0.12	22	6.7	3.9	0.6	0.2	1.4	2.3	57.9	0.58
	7.4	0.12	30	9.2	6.8	0.7	0.2	2.8	4.5	61.8	0.74
	9.8	0.12	45	16.5	12.6	0.7	0.3	5.5	8.8	62.9	0.76
	14.7	0.12	52	17.4	14.3	0.8	0.5	9.6	11.0	**87.3**	**0.82**
MNB	4.9	0.04	60	6.7	3.5	0.6	0.2	1.2	2.1	58.7	0.52
	7.4	0.04	90	9.2	6.7	0.7	0.2	2.8	4.4	62.7	0.73
	9.8	0.04	150	16.5	13.2	0.7	0.2	6.2	9.2	66.7	0.80
	14.7	0.04	165	18.4	15.7	0.8	0.2	10.2	12.1	**83.9**	**0.85**

Table : The measuring values of the brake power, power efficiency and power factor tor two AC electric motor AC motor Turbo QB60 and NS-70

AC motor	Force N	arm Length, cm	Rotational speed, rpm	Volt Out, V	AC Current, A	Brake Power, w	True power, W	Apparent power, W	Power efficiency %	Power factor (cos Φ)
Turbo motor	4.9	0.12	1070	220.0	0.6	65.9	75.0	132.0	49.9	0.57
	7.4	0.12	1132	220.0	0.9	104.6	139.0	198.0	52.8	0.70
	9.8	0.12	1237	220.0	1.3	152.4	214.0	286.0	53.3	0.75
	14.7	0.12	1339	220.0	1.6	247.5	273.0	352.0	**70.3**	**0.78**
N3-70 motor	4.9	0.03	620	220.0	0.1	9.5	11.8	22.0	43.4	0.54
	7.4	0.03	640	220.0	0.13	14.8	17.3	28.6	51.7	0.60
	9.8	0.03	750	220.0	0.16	23.1	24.0	35.2	65.6	0.68
	14.7	0.03	780	220.0	0.18	36.0	32.1	39.6	**91.0**	**0.81**

SUMMARY AND CONCLUSIONS

The result indicated the students may be able to measure and test the electrical DC and AC motor to know the performance of the electrical motor that applied in agricultural machine. Students can gain valuable insight into the operating characteristics of electric motors through such activities. As well as, it may able to study the effect of some parameters such as rotational speed on the efficiency of electrical motors. The power factor and power efficiency may able to measure for AC motor directly without calculating the angle electric phase. As well as, it could be recommended that the Prony brake laboratory unit test for electric motor should be redesigned to test of the heavy electric motors.

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الملخص العربى

وحدة معملية لأختبار أداء المحرك الكهربى

د. السيد محمود البيلى صحصاح

تهدف هذه الدراسة الى البحث فى أمكانية تصنيع و بناء نموذج معملى رخيص التكاليف تحت الظروف المصرية يسهل تطبيقة لأختبار المحرك الكهربى ذو التيار المستمر DC و المتردد AC. و ا لذى يصعب أختباره فى مصر ، حيث أن وحدات أختبار المحرك الكهربى باهظة الثمن و بخاصة لطلاب الهندسة الزراعية و الباحثين. و قد أجريت الدراسة فى معمل قسم الهندسة الزراعية بكلية الزراعة جامعة كفرالشيخ و ذلك ببناء اطار من الألومنيوم ذو أبعاد ٤٥٠ مم x ٤٥٠ مم ثبت بداخله عمود من الصلب ينزلق علية الميزان و مثيت على مسافة ٣ سم من أعلى و به ميزان من الزنبرك بدقة ٣٠٠ جم بحد أقصى ٢٠ ك.جم و أقصى عزم يتحملة ٨٠٠ ك.جم سم (٧,٨٥ x ١٠ ^{٣} نيوتن .سم) . كما تم عمل قاعدة لتثبيت المحرك الكهربى المراد أختبارة فى الأطار و أيضا فرملة ثبت فى أحد نهايتها قضيب من الحديد الصلب(قضيب منزلق) ليعلق فى طرف الميزان لقياس العزم الناتج من المحركات الكهربية DC و AC موضع الأختبار، كما تم تركيب لوحة كهربية بها مفتاح لتغيير فرق الجهد و شدة التيار الداخل للمحركات المستمرة التيار و منظم للسرعة فى المحركات المترددة التيار. أيضا تم توصيل جهاز الفولتميتر و الأميتر و الواتميتر لقياس فروق الجهد و شدة التيار الداخل و الخارج عند أختبار المحرك. كما ثبت جهاز قياس السرعة الدورانية موديل Tachometer model HP على مسافة ١٥ سم لقياس السرعة الدورانية عند كل وضع من أوضاع الحمل المختلفة و التى قدرت بالأزاحة التى يثبت عندها ذراع العزم على القضيب المنزلق. كما أجريت التجارب بأختبار أربعة أنواع من المحركات الكهربية أثنين منها ذو تيارمتردد هم AC motor model N3-70, و AC motor model Turbo QB60 و محركين ذو تيار مستمر هم DC motor KAG, NMB 12 V,و تم تسجيل البيانات لتقدير لقدرة الفرملية و القدرة الكهربية الدخلة للمحرك أى بدون حمل و القدرة الكهربية بحمل لحساب كفاءة المحرك و معامل القدرة للمحرك المستمر و المتردد. و أتضح من النتائج أنه يمكن قياس و تقديركفاءة و أداء المحركات الكهربية ذات القدرات الصغيرة و التى غالبا ما تستعمل فى مجال الزراعة من أدارة المعدات الزراعية المختلفة و تصنيع الألبان و التصنيع الغذائى و العلف و رفع المياه و بخاصة المحرك الكهربى ذو التيار المتردد. و قد بلغت كفاءة القدرة المقاسة بواسطة وحدة الأختبار المعملية للمحرك الكهربى المتردد التيار من النوع N3-70 قيمة ٩١ % مقارنة بكفاءة كهربية ٨٧,٣ % ، ٨٣,٧ % و ٧٠,٣% لكل من المحركات الكهربية KAG و MNB و AC turbo.

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