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Report for Experiment #7

Separate Winding "SW" Squirrel Cage Motor

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Abstract:

The aim of experiment:

The experiment was done to show how we can change the speed of Squirrel Cage induction Motor using pole-changer (separate windings).

Method used:

1)Separate Winding “SW” Squirrel Cage Motor

2)Voltage measurement.

3)Current and power factor measurement.

4)Pole-changer to change the speed of rotation .

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Theory:

To study and operate a three phase changeable pole induction motor having two separate windings which let it operates at two different speeds.

The induction (asynchronous) motor is one of the most important machines in the area of polyphase machines because of its low cost and high operational safety, also its preferred for a broad power range of unregulated drive mechanisms.

The design of the rotor, squirrel cage or slip ring, various the types of asynchronous motors.

The three outer conductors of the three-phase system produce the stator rotating magnetic field, which rotates at a synchronous speed (n_S)

$$ns = \frac{120fe}{p}$$

Where f_e is the electrical frequency & P is the number of poles.

So we can control the speed of the motor by changing the number of poles, but this requires a set of separate windings on the motor which will increase the cost of the motor.

However, the rotor rotates at a speed called mechanical speed (n_m) which is less than the synchronous speed.

$$nm = (1 - s)ns$$

Where s is called the slip and equal to

$$s = \frac{(ns - nm)}{ns}$$

Procedure & Data discussion :

Part A. Basic Circuit

The circuit shown in the Figure 1 was connected to drive the squirrel cage induction motor

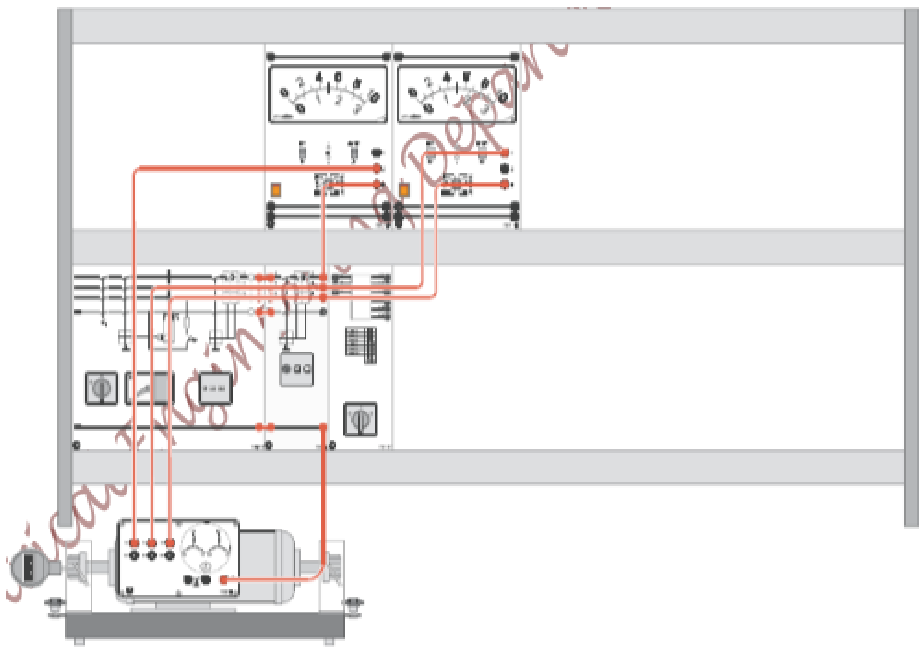

Figure 1

And to studying the behavior of the induction motor the circuit shown in Figure 2 cleared the connection

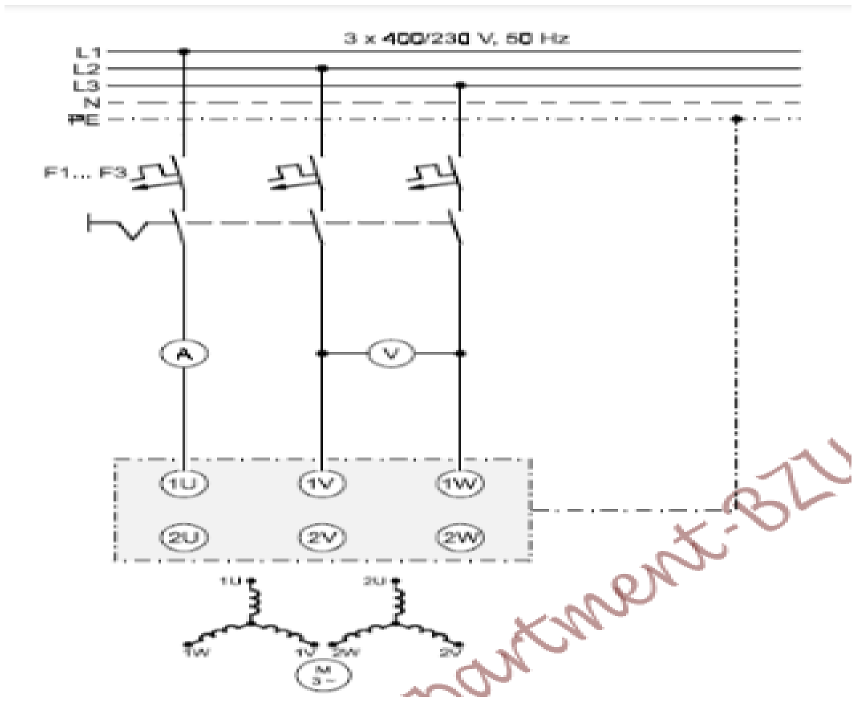

Figure 2

Using voltage and current measurement ,the line to line voltage equal 400 and the phase current equal 0.6 A , and the speed of rotation was measured and equal 1000 rev/min .

The number of poles can be calculated using the following equation (mentioned in theory)

$ns = \frac{120fe}{p}$ $p = \frac{120fe}{ns}$ **= 6 pole's .**

The circuit in Figure 3 was connected to verify the speed control using poles changing

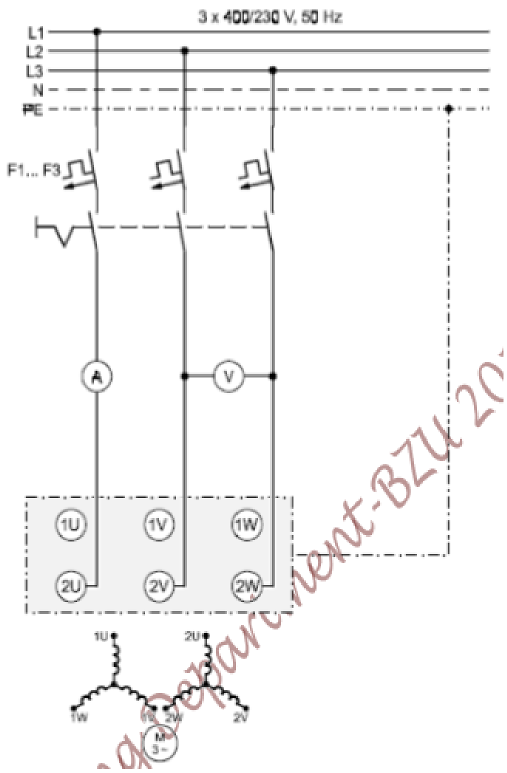

Figure 3

Using voltage and current measurement ,the line to line voltage equal 400 and the phase current equal 0.75 A , and the speed of rotation was measured and equal 1500 rev/min .

The number of poles can be calculated using the following equation (mentioned in theory)

$$ns = \frac{120fe}{p} \qquad\qquad p = \frac{120fe}{ns} = 4 \text{ pole's .}$$

Noticed that as the number of pole decrease the speed of the induction motor will increase (i.e invers relation) .

Part B :Determining Efficiency and Recording Characteristics in Motor Operation

a)**Efficiency Calculations**

Using the data printed on the name plate of the machine to fill Table 1

Table 1

Nominal Voltage V_N	400
Nominal current I_N (low speed)	0.6
Nominal Current I_N (high speed)	0.7
Nominal Power Factor, $Cos(\theta_N)$ (low speed)	0.71
Nominal Power Factor, $Cos(\theta_N)$ (high speed)	0.72
Nominal speed n_N (low speed)	880
Nominal speed n_N (high speed)	1390
Nominal Power P_N (low speed)	110
Nominal Power P_N (high speed)	200

The circuit in the Figure 4 was connected as shown below

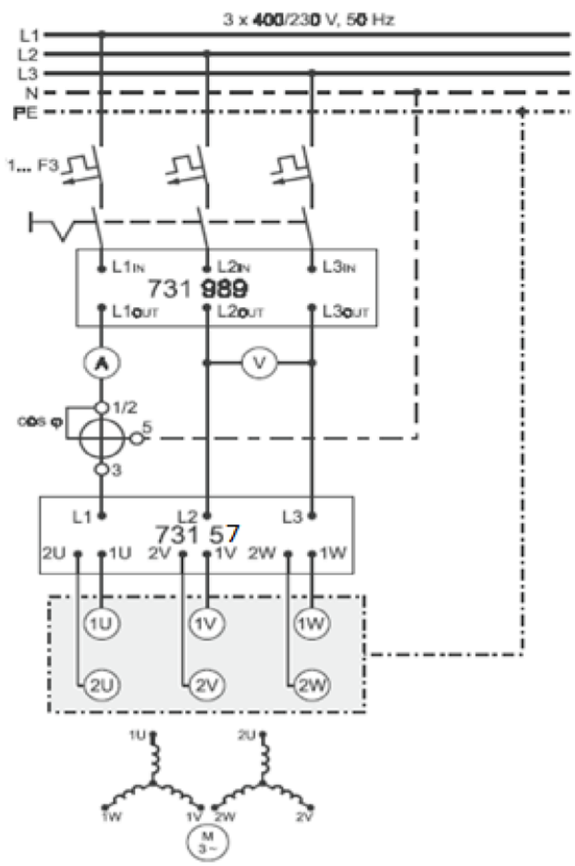

Figure 4

The voltage and current and power factor measurement was used to measure a data at low speed and high speed

low speed

$V_{L\text{-}L}$ = 400V I_θ = 0.6 A N_m = 1000 rev/min PF = 0.7

High speed

$V_{L\text{-}L}$ = 400V I_θ = 0.7 A N_m = 1490 rev/min PF = 0.72

The nominal torque was calculated using the data in Table 1

low speed

$\tau_n = P_n/w_n = 110/(880*2*\pi/60) = 1.19$ N.m

High speed

$\tau_n = P_n/w_n = 200/(1390*2*\pi/60) = 1.37$ N.m

The input nominal power can be calculated as below

low speed

$P_{in} = \sqrt{3} * V_{L\text{-}L} * I * Pf$ = 295.1 W

High speed

$P_{in} = \sqrt{3} * V_{L\text{-}L} * I * Pf$ = 344 W

The efficiency can be calculated theoretically as shown bellow

low speed

$\eta = P_{out}/P_{in} = 110/295.1 = 37.1$ %

High speed

$\eta = P_{out}/P_{in} = 200/344 = 58.13$ %

b) Load Characteristics :

Using the connection in Figure 4 , The motor was loaded and the torque was increasing sequentially then the data recorded in Table 2

Table 2

	$T/T_{N,act}$	**0.0**	**0.1**	**0.2**	**0.3**	**0.4**	**0.5**	**0.6**	**0.7**
	$T/[Nm]$	$0.0XT_N$	0.119	0.238	0.357	0.476	0.595	0.741	0.833
Measure	$n/[rpm]$	994	986	981	977	970	962	954	943
	$I/[A]$	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7
	Cos (θ)	0.75	0.65	0.6	0.6	0.55	0.55	0.54	0.51
calculate	n/n_N	1.129	1.12	1.11	1.11	1.10	1.09	1.08	1.07
	$I/I_{N,act}$	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16
	$P_1/[W]$	363.7	315.2	290.1	270	247.6	247.6	247.6	230
	P_1/P_{1N}	1.24	1.08	1	0.93	0.85	0.85	0.85	0.79
	$P_2/[W]$	0	12.2	24.4	36.5	48.3	54.8	74	82.2
	P_2/P_{2N}	0	0.11	0.22	0.33	0.43	0.5	0.672	0.747
	Ŋ	0	0.038	0.093	0.135	0.19	0.221	0.32	0.357
	$T/T_{N,act}$	**0.8**	**0.9**	**1.0**	**1.1**	**1.2**	**1.3**	**1.4**	**1.5**
	$T/[Nm]$	0.952	1.07	1.19	1.309	1.428	1.547	1.666	1.785
Measure	$n/[rpm]$	935	924	910	898	878	852	815	790
	$I/[A]$	0.65	0.65	0.65	0.65	0.65	0.67	0.75	0.8
	Cos (θ)	0.5	0.5	0.48	0.45	0.4	0.35	0.3	0.3
	n/n_N	1.06	1.05	1.03	1.02	0.997	0.96	0.92	0.897
calculate	$I/I_{N,act}$	1.08	1.08	1.08	1.08	1.08	1.11	1.25	1.33
	$P_1/[W]$	225	225	216	202.6	180.1	162.4	155.8	166.2
	P_1/P_{1N}	0.77	0.77	0.74	0.69	0.62	0.56	0.53	0.6
	$P_2/[W]$	93.1	103.4	113.3	123	131.2	138	141.6	147.6
	P_2/P_{2N}	0.84	0.94	1.03	1.11	1.19	1.25	1.28	1.34
	Ŋ	0.41	0.46	0.52	0.607	0.72	0.85	0.90	0.88

The following diagram shown the relation between the induced torque and (n/n_r, I/I_N, P_1/P_N, P_2/P_N ,Cos (θ)and **ŋ**)

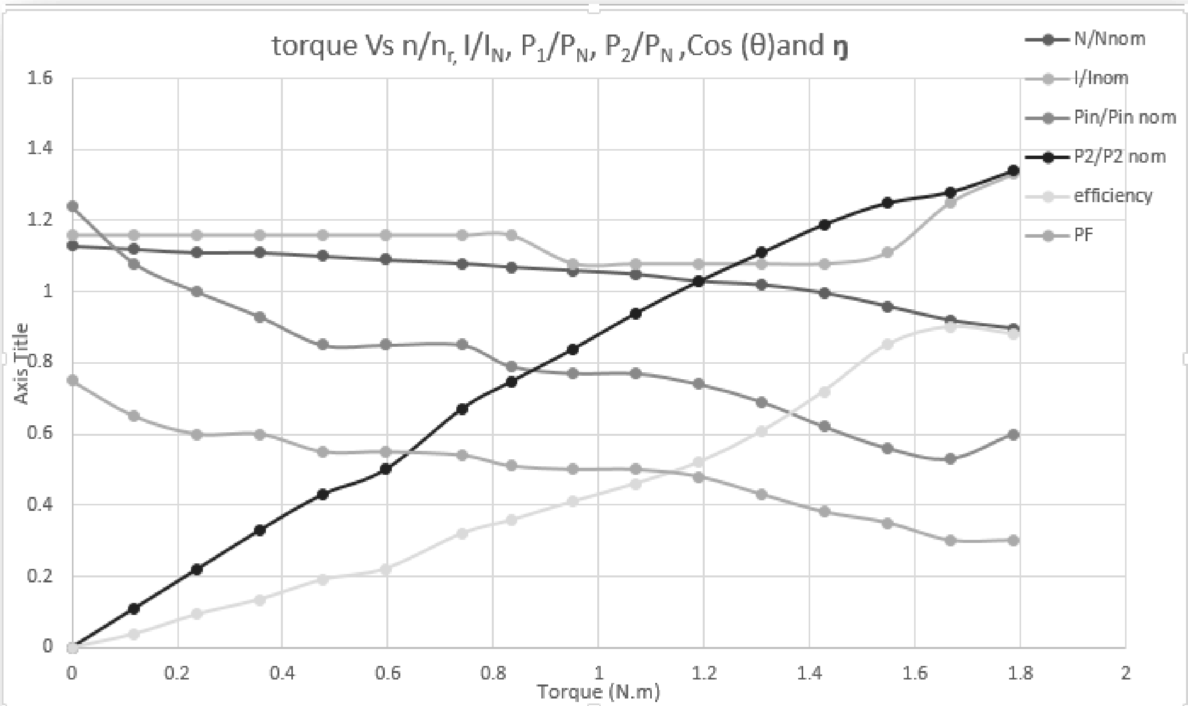

Figure 5

Noticed that the efficiency has good improvement as the motor operated near the rated torque also the power factor decayed sharply as the load increase ,the input current was still constant even the load exceed the rated torque

*note: these relation in Figure 5 talked at low speed(6 poles)

The pole's changer was set to give at high speed then the data was measured and filled in Table 3

Table 3

	T/$T_{N,act}$	0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7
	T/[Nm]	0.0XT_N	0.137	0.274	0.441	0.545	0.68	0.882	0.954
Measure	n/[rpm]	1493	1487	1480	1473	1467	1461	1450	1449
	I/[A]	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.71
	Cos (θ)	0.8	0.8	0.8	0.7	0.65	0.6	0.55	0.5
calculate	n/n_N	1.07	1.06	1.06	1.055	1.053	1.05	1.043	1.042
	I/$I_{N,act}$	1	1	1	1	1	1	1	1.04
	P_1/[W]	387.9	387.9	387.9	339.4	315.2	290.9	266.7	242.4
	P_1/P_{1N}	1.1	1.1	1.1	0.96	0.9	0.83	0.762	0.69
	P_2/[W]	0	21.3	38.2	67.99	83.7	103.9	133.8	144.6
	P_2/P_{2N}	0	0.10	0.19	0.34	0.41	0.51	0.669	0.72
	Ŋ	0	0.054	0.098	0.20	0.265	0.35	0.50	0.59
	T/$T_{N,act}$	0.8	0.9	1.0	1.1	1.2	1.3	1.4	1.5
	T/[Nm]	1.096	1.223	1.37	1.507	1.644	1.781	1.918	2.055
Measure	n/[rpm]	1437	1428	1418	1407	1397	1387	1369	1320
	I/[A]	0.75	0.75	0.8	0.8	0.83	0.86	0.9	0.95
	Cos (θ)	0.5	0.45	0.45	0.4	0.4	0.4	0.4	0.4
calculate	n/n_N	1.03	1.02	1.02	1.01	1	0.99	0.98	0.94
	I/$I_{N,act}$	1.07	1.07	1.14	1.14	1.18	1.22	1.28	1.35
	P_1/[W]	259.6	233.8	249.4	221.7	230	238.3	249.4	260.5
	P_1/P_{1N}	0.74	0.668	0.71	0.63	0.65	0.59	0.53	0.564
	P_2/[W]	160.7	182.8	203.3	215	220	225	240	253
	P_2/P_{2N}	0.80	0.914	1.01	1.07	1.1	1.125	1.2	1.265
	Ŋ	0.619	0.78	0.81	0.97	0.95	0.94	0.96	0.97

The following diagram shown the relation between the induced torque and (n/n_r, I/I_N, P_1/P_N, P_2/P_N ,Cos (θ)and **ŋ**)

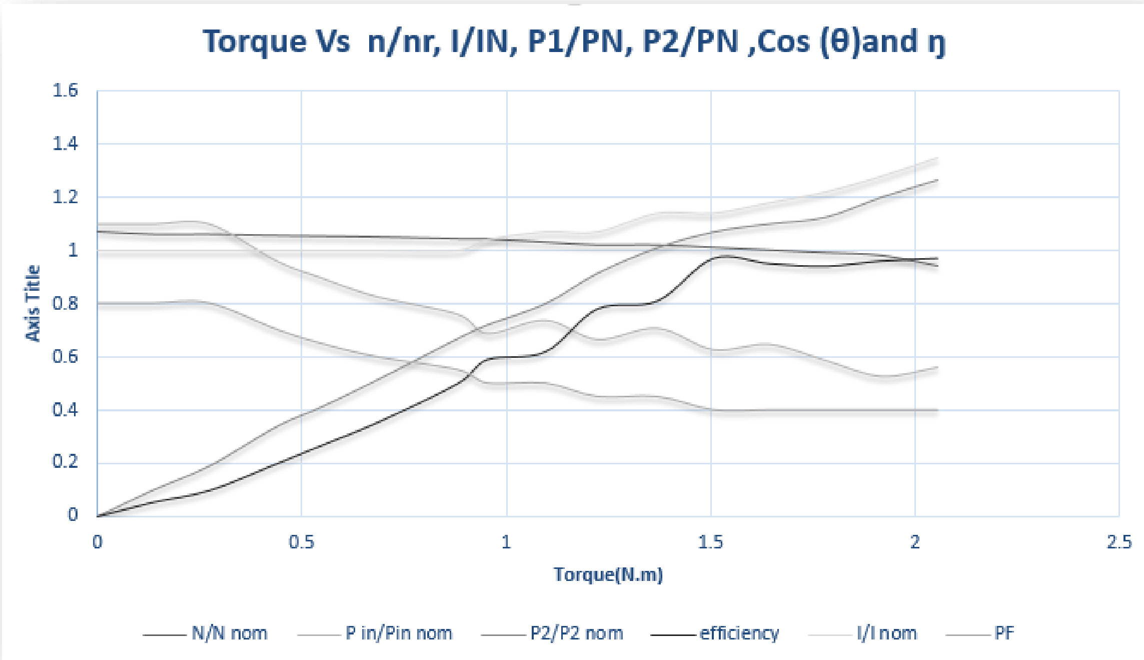

Figure 6

Noted that ,the rated torque will increase as the rated speed of the motor increase ,the efficiency has good improvement as the motor operate at rated torque

*note: these relation in Figure 6 talked at high speed(4 poles).

part C :Computer based Recording of Run-up Characteristics

In this part , the computer was used to plot curves that represent the behavior of the motor once when operating with the high speed another when operating on the low speed

The figure below shown the torque – speed characteristic for the squirrel cage induction motor at low speed and high speed

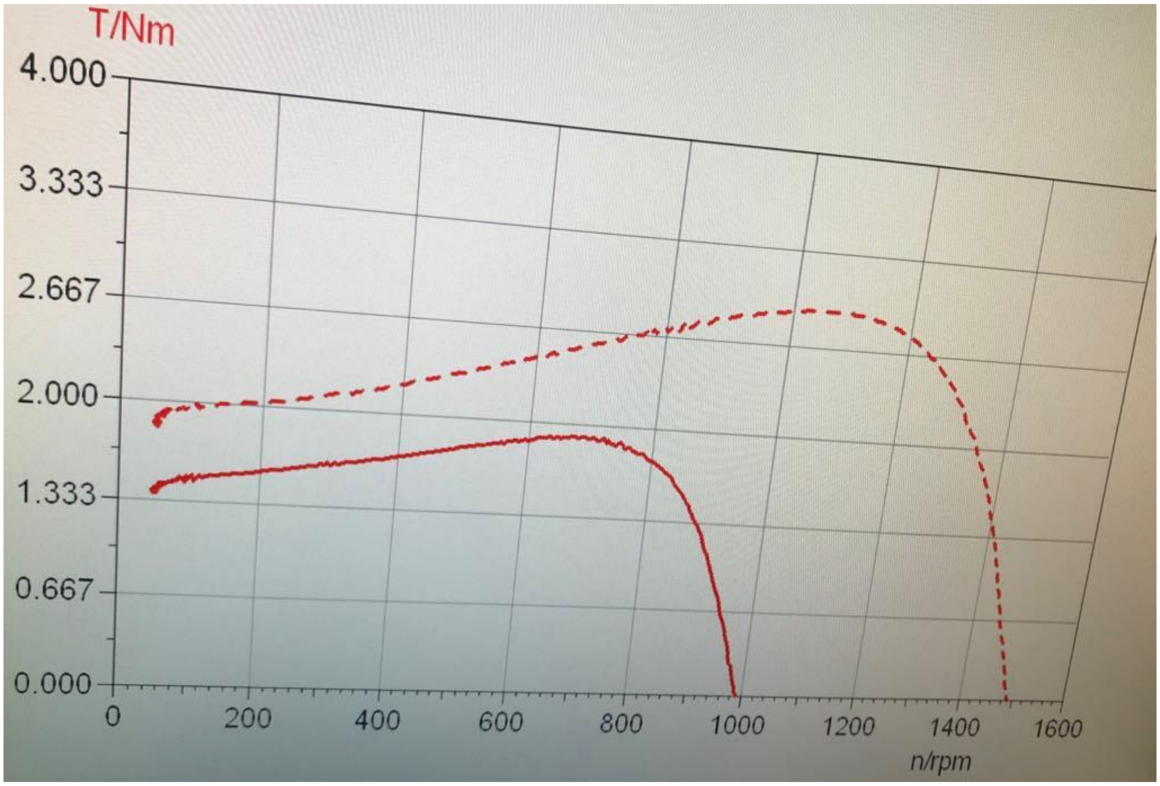

Figure 7

From the Figure above, Noticed that the pullout torque in high speed case is large than low speed, also the starting torque is large too

Conclusion:

In This Experiment , separate winding “SW” Squirrel Cage Motor was used , and noticed that each winding has different numbers of poles.

In each case ,the motor has different characteristic from the other case(τ_N , I_N,P_N) , and the efficiency of the motor will be maximum at rated torque of the motor .

there is a small difference between the theoretical data value's of the motor (printed on name plate) and the data that was measured experimentally due to uncelebrated equipment or humans error in taking data.

References:

Electrical Machinery Fundamental "fifth edition"