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Manual Performance Analysis of a 2.2kw Refurbished Three-Phase Induction Motor

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Abstract: *A refurbished 2.2kW 3-phase squirrel-cage induction motor was subjected to a steady-state performance analysis. It was earlier refurbished to reflect a prevailing local maximum 3-phase voltage level of $380V_{ac}$, as against the manufacturer's name-plate nominal voltage of $415V_{ac}$. The aim was to obtain from the motor at $380V_{ac}$ satisfactory values of the operational quantities as obtainable at the original voltage level of $415V_{ac}$. To this end the method of open-circuit/short-circuit laboratory tests was adopted, the d.c. resistance test notwithstanding. The experimental calculations from these led to the determination of the machine equivalent circuit parameters by means of which the motor operational quantities and the performance curves for analytical purposes were obtained. MATLAB was used to generate the performance curves via the appropriate mathematical models. The analysis showed the motor as exhibiting satisfactory full-load values of torque, speed, output power, slip and power factor, although at the expense of full-load efficiency and starting properties.*
***Keywords*:** *Refurbished Induction Motor, Performance Analysis*

I. Introduction & Motor Data

1.1 Introduction

Since the advent of rotating machines in 1833 [Say & Taylor, 1980], the induction motor as a rotating machine has been of immense significance to mankind. When it breaks down under such adverse operational conditions as mechanical overloading, short-circuited turns, single-phasing, under-voltage/over-voltage conditions and ageing, it requires to be refurbished [Mehala N. (2010)]. The machine of interest in this paper is a burnt 2.2kW, 415V, squirrel-cage induction motor. It got burnt-out due to protracted overheating arising from under-voltage condition of operation overnight. After refurbishment, it became necessary to subject it to a steady-state manual performance analysis (*manual* in the sense of the absence of computer aid in calculations). Thus, the work in this paper commences proper with the production of the necessary machine equations in Section 2.0. In Section 3.0 the authors shall present tabulated laboratory experimentation results. The experimental calculations from experimentation results and the associated performance curves are dwelt upon in Section 4.0; whilst, in Section 5.0 performance analysis, conclusion and recommendation are dealt with.

1.2 Motor Data

The complete machine name-plate data are as tabulated below

Table 1.1: Name-plate Details of the Test Machine

i) Manufacturer …BRUSH	***v)*** Current…………4.9A(Δ)	***ix)*** Rotor Speed ….1420rpm
ii) Country ……….England	***vi)*** cosφ ……………Nil	***x)*** Frequency …….50H$_Z$
iii) Output power …2.2kW	***vii)*** Efficiency (ŋ) ….Nil	***xi)*** Duty Rating …..CMR
iv) Voltage ………..415V(Δ)	***viii)*** Phases ………….3	xii) Insulation Class ..…B

II. Applicable Machine Equations

The machine equations applicable for the production of the various quantities and performance curves of the test motor are as summarized below.

2.1 Stator Input Current (On New Voltage Rating), $I_{s(new)}$:

$$I_{s(new)} = I_{s(old)} x[V_{s(old)}/V_{s(new)}] \quad \text{.......(2.1)}$$

2.2 Effective Load Current, I_{rs}:

$$I_{rs} = \frac{V_s}{\sqrt{\left\{\left(R_s + R_{rs}/s\right)^2 + \left(X_s + X_{rs}\right)^2\right\}}} \quad Amps \text{... ....(2.2a)}$$

$$= (I_{s(new)} - I_{oc}) \quad Amps \quad \text{.......(2.2b)}$$

2.3 Gross (or Developed) Output Power (Mechanical), $P_{o(G)}$:

$$P_{o(G)} = m\,I_{rs}^{2}\left[R_{rs}(1-s)/s\right] \quad \textit{Watt.} \quad \ldots\ldots(2.3)$$

2.4 Maximum Output Power, $P_{o(MAX)}$:

$$P_{o(MAX)} = mV_s \frac{I_{sc(\max)} - I_o}{2(1+\cos\varphi_{sc})} x10^{-3} \quad kW \ldots\ldots 2.4a)$$

$\cos\varphi_{sc} = P_{sc}/\sqrt{3}xV_{sc}xI_{sc}$ *lagging* ***(short-circuit power factor)****….* (2.4b)

2.5 Gross (or Developed) Torque (Mechanical), $T_{(G)}$:

$$T_{(G)} = P_{0(G)}/\omega_r = \frac{m\,I_{rs}^{2}R_{rs}(1-s)/s}{(2\pi n_r)/60} \quad \textit{N-m} \ldots\ldots(2.5a)$$

$$= \frac{m\,I_{rs}^{2}R_{rs}/s}{(2\pi n_s)/60} \quad \textit{N-m} \ldots\ldots(2.5b)$$

2.6 Ratio of Torque at Any Slip to The Pull-Out Torque, $T/T_{(PO)}$:

$$T/T_{(PO)} = 2\Big/\left(\frac{s}{s_{po}} + \frac{s_{po}}{s}\right) \quad \ldots\ldots(2.6a)$$

$$s_{po} \approx \frac{(1+\tau_1)R_{rs}}{X_s + (1+\tau_1)X_{rs}} \quad ; \quad \tau_1 = X_s/X_m \quad \ldots\ldots(2.6b)$$

2.7 Full-Load Power Factor, $\cos\varphi_{rs}$:

$$\cos\phi_{rs} = \frac{R_s + R_{rs}/s}{\sqrt{\left[\left(R_s + R_{rs}/s\right)^2 + \left(X_s + X_{rs}\right)^2\right]}} \quad \textit{lagging} \quad \ldots\ldots(2.7)$$

2.8 Open-Circuit Leakage Reactance, X_{oc}:

$$X_{oc} = \left\{\left(\frac{\sqrt{3}V_{oc}}{I_{oc}}\right)^2 - \left(\frac{P_{oc}}{I_{oc}^2}\right)^2\right\}^{1/2} = X_s + X_m \quad \textit{ohms.} \ldots\ldots(2.8)$$

2.9 Short-Circuit Leakage Reactance, X_{sc}:

$$X_{sc} = \left\{\left(\frac{\sqrt{3}V_{sc}}{I_{sc}}\right)^2 - \left(\frac{P_{sc}}{I_{sc}^2}\right)^2\right\}^{1/2} = X_s + X_{rs} \quad \textit{ohms.} \ldots\ldots(2.9)$$

2.10 Short-Circuit Leakage Resistance, R_{sc}:

$R_{sc} = P_{sc}/I_{sc}^2 = R_s + R_{rs}$ ……………………………………………(2.10

2.11 Power Balance Equations:

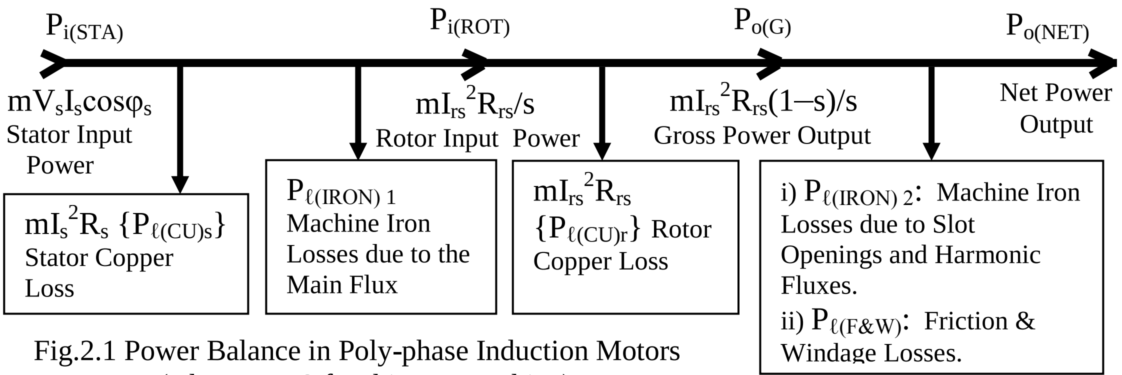

Fig.2.1 Power Balance in Poly-phase Induction Motors (where m = 3 for this test machine).

The power distribution in a poly-phase induction motor is as shown in Fig.2.1 and from this power balance diagram we have

2.11.1 Net Output Power, $P_{o(NET)}$:

$P_{o(NET)} = P_{o(G)} – (P_{\ell(IRON)\,2} + P_{\ell(F\&W)})$ …………………………..(2.11)

2.11.2 Total Fixed Losses, $P_{\ell(FXD)T}$:

$P_{\ell(FXD)T} = P_{\ell(IRON)1} + P_{\ell(IRON)2} + P_{\ell(F\&W)} = P_{oc} – mI_{oc}^2R_s$ ………..(2.12)

2.11.3 Total Motor Losses, $P_{\ell(TOT)}$:

$P_{\ell(TOT)} = P_{\ell(FXD)T} + P_{\ell(CU)T} = P_{\ell(FXD)T} + P_{sc}$ ……………………...(2.13)

2.11.4 Input Power Factor, $\cos\varphi_s$,:

$\cos\varphi_s = \{P_{o(NET)} + P_{\ell(TOT)}\}/mV_sI_s$ ……………………………….(2.14)

2.12 Full-Load Efficiency, η:

$\eta = P_{o(NET)} /\{P_{o(NET)} + P_{\ell(TOT)}\}$ ………………………………….(2.15)

2.13 Full-Load Rotor Speed, n_r:

$n_r = n_s(1– s_{fl})$ ……………………………………………………(2.16)

2.14 Mechanical Loss Torque, $T_{(loss)}$:

$T_{(loss)} = 60(P_{\ell(IRON)\,2} + P_{\ell(F\&W)})/2\pi\, n_s$ ………………………….(2.17)

2.15 Delivered Full-Load (Mechanical) Torque, $T_{(FL)}$:

$T_{(FL)} = T_{(G)} – T_{(loss)}$ ……………………………………………(2.18)

2.16 Ratio of Starting Torque to Delivered Full-Load Torque, $T_{(ST)}/T_{(FL)}$:

$T_{(ST)}/T_{(FL)} = (I_{s(max)} /I_{rs})^2 x\ s_{fl}$ ………………………………….(2.19)

{N.B.: The equations were as obtained from [Shepherd et. al., 1970]; [Kostenko & Piotrovsky, 1977]; [Daniels, 1976]; [Liwschitz-Garik & Whipple, 1970]; [Mittle & Mittal, 1998); [Say, 1976]; V_s – stator input voltage (nominal); V_{oc} – applied open-circuit voltage ; V_{sc} – applied short-circuit voltage; R_s – stator winding resistance; R_{rs} – rotor cage resistance referred to stator; X_s – stator leakage reactance; X_{rs} – rotor leakage reactance referred to stator; X_m – magnetizing reactance; I_s – stator input current (nominal); I_{oc} or I_o – open-circuit current; I_{sc} – short-circuit current on r*educed voltage*; $I_{sc(max)}$ – short-circuit current on full voltage; P_{oc} – open-circuit power dissipation; P_{sc} – short-circuit power dissipation; $\cos\varphi_{sc}$ – short-circuit power factor; s – any slip; s_{fl} – full-load slip; s_{po} – slip for the pull-out torque; m – no. of phases; ω_r – rotor angular velocity; T– torque at any slip; n_r – rotor speed; n_s – synchronous speed; other terms being as described in Fig.2.1 or in the sub-headings**}**.

III. Laboratory Experimentation Results

The Open-Circuit, Short-Circuit and D.C. Resistance Tests were carried out following the usual laboratory procedures. Care was exercised to connect the motor in star (Y) for the D.C. Resistance Test and in delta (Δ) for the other tests. The results obtained were as presented in Table 3.1 below. However, prior to this, it was necessary to calculate the new input current demand (i.e. stator current for 380V) since the short-circuit current on r*educed voltage* shall be of the same value. Thus, from equation 2.1 we obtain the following *with motor on* Δ *connection* as required

$I_{s(new)} = 4.9x[415/380] = 5.35$ or 5.4 Amps $= I_{sc}$

Table 3.1 Open-Circuit, Short-Circuit Test and D.C. Resistance Tests Results

TYPE OF TEST	APPLIED VOLTAGE	CURRENT DRAWN	POWER CONSUMED	REMARKS
OPEN-CIRCUIT	V_{oc} = 330V	I_{oc} = 1.2A	P_{oc} = 360W	Motor connected in DELTA. Tests @ 35^0C
SHORT-CIRCIUT	V_{sc} = 150V	I_{sc} = 5.4A	P_{sc} = 720W	
STATOR D.C. RESISTANCE TEST, $R_{s(DC)}$ (per-phase) = 16.7Ω [@ 28^0C, Motor Body Temperature.]			**OPEN-CIRCUIT (OR NO-LOAD) ROTOR SPEED,** n_r = 1500rpm, as measured with DAWE Stroboscope, Type 1214B	
NB: ***The local supply voltage measured at the time was 330V, 3-phase; Hz = 50***				

IV. Calculations From Experimentation

RESULTS AND PERFORMANCE CURVES

4.1 Calculations from D.C. Test Results:

Stator Resistance, $R_{s(d.c.)}$ and $R_{s(a.c.)}$ [Enyong, 2008]:

$$R_{s(d.c.)}\ @35\deg.C = 16.7x\frac{234.5+35}{234.5+28} = 17.1\Omega$$

But, a.c. resistance should be used. According to [Sadat, 1999], the a.c. resistance at 60Hz is about 2% higher than d.c. resistance. Thus, by simple proportion, it will be
smaller at $50H_z$ by the factor (50/60), ie 0.833x2 or 1.7%. Thus,

$R_{s(a.c.)}$ @ 35 deg.C = 1.017x17.1 = 17.4Ω

4.2 Calculation from the Open-Circuit Test Results:

Combined Stator Leakage and Magnetizing Reactances ($X_s + X_m$), from (2.8):

$$X_{oc} = \left\{ \left(\frac{\sqrt{3}x330}{1.2} \right)^2 - \left(\frac{360}{1.2^2} \right)^2 \right\}^{1/2} = X_s + X_m = 405.4\Omega$$

4.3 Calculations from the Short-Circuit Test Results:

a) Combined Stator and Rotor Leakage Reactances ($X_s + X_{rs}$), from (2.9):

$$X_{sc} = \left\{ \left(\frac{\sqrt{3}x150}{5.4} \right)^2 - \left(\frac{760}{5.4^2} \right)^2 \right\}^{½} = X_s + X_{rs} = 41.3\Omega$$

b) Combined Stator and Rotor Resistances ($R_s + R_{rs}$), from (2.10):

$$R_{sc} = 720 / 5.4^2 = R_s + R_{rs} = 24.7\Omega$$

4.4 Other calculations from All the Results Above:

(a) Separation of X_s and X_{rs}

Taking them to be equal according to [Say, 1976], will yield

$\mathbf{X_s} = \mathbf{X_{rs}}$ = 41.3/2 = **20.7Ω**

b) Separating X_s and X_m : $\mathbf{X_m}$ = 405.4 – 20.7 = **384.7Ω**

c) Separating R_s and R_{rs} **:** $\mathbf{R_{rs}}$ = 24.7 – 17.4 = **7.3Ω**

***d) Effective Load Current**, from (2.2b):* $\mathbf{I_{rs}}$ = 5.4 – 1.2 = **4.2A**

e) Total Fixed Losses**, from (2.12)**: $\mathbf{P_{\ell(FXD)T}}$ = 360 – 3(1.2/√3)^{2}x17.4 = **335W**

***f) Total Machine Losses, $P_{\ell(TOT)}$**, from (2.13) and from Fig.2.1:*

$\mathbf{P_{\ell(TOT)}}$ = 335 + 720 = **1055W**

4.5 Calculations based on Parameters derived from Performance Curves

4.5.1 Full-Load Slip(s_{fl}) from The Current/Slip Curve:

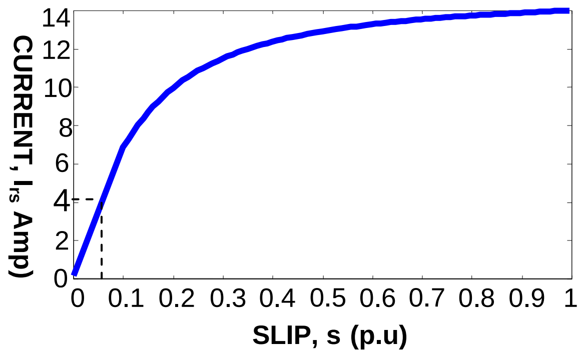

Fig.4.1: Current/Slip Performance Characteristic Curve

The current/slip curve as generated by means of MATLAB using equation 2.2a is as shown in Fig.4.1. The full-load slip, s_{fl} , being the slip for the current, I_{rs} = 4.2A as indicated on the curve is **0.053p.u.** Based on this value of full-load slip we calculate the following parameters:

a) *Full-Load Rotor Speed, n_r , using (2.16):*

Since the rotor speed on no load is virtually the synchronous speed, n_s , because the slip on open circuit is virtually zero according to [Theraja, 1997] and as can be observed from Fig.4.1, we have that n_s = 1500r.p.m. (see Table3.1). Therefore,

$\mathbf{n_r}$ = 1500(1 – 0.053) = **1,420r.p.m.**

b) Gross or Developed (Mechanical) Output Power, $P_{o(G)}$, using equation (2.3):

$\mathbf{P_{o(G)}}$ = 3(4.2/√3)^{2}x7.3(1 – 0.053)/0.053 = **2,301W**

c) Friction & Windage Losses, $P_{\ell(F\&W)}$:

A typical value of $P_{\ell(F\&W)}$ has been given as 44W for a 3Hp (or 2.24kW) 3-phase cage induction motor at 60Hz (see p.146 of [Liwschitz-Garik & Whipple, 1970]). This amounts to approximately 2% of the rated output power. The same shall be adopted at 50Hz for the test machine of 2.2kW without attendant significant error for a 10Hz difference in frequency. Thus, $\mathbf{P_{\ell(F\&W)} = 44W}$.

d) Total Iron Losses, $P_{\ell(IRON)T}$, from (2.12):

$\mathbf{P_{\ell(IRON)T}} = P_{\ell(FXD)T} - P_{\ell(F\&W)} = 335 - 44 = \mathbf{291W}$

e) Iron Losses due to Slot Openings & Harmonic Fluxes, $P_{\ell(IRON)2}$:

According to [Liwschitz-Garik & Whipple, 1970]), we can assume that

$\mathbf{P_{\ell(IRON)2}} = P_{\ell(IRON)1} = \frac{1}{2}P_{\ell(IRON)T} = 291/2 = \mathbf{145.5W}$

f) Gross or Developed (Mechanical) Torque, $T_{(G)}$, from (2.5b):

$$\mathbf{T_{(G)}} = \frac{3x\left(4.2/\sqrt{3}\right)^2 x7.3/0.053}{(2x\pi x1500)/60} = \mathbf{15.47N\text{-}m}$$

g) Mechanical Loss Torque, $T_{(loss)}$, from (2.16):

$\mathbf{T_{(loss)}} = 60x(145.5 + 44)/2x\pi x1500 = \mathbf{1.21N\text{-}m}$

h) Net or Delivered (Mechanical) Output Power, from (2.11):

$\mathbf{P_{o(NET)}} = 2{,}301 - (145.5 + 44) = \mathbf{2{,}112W}$

i) Delivered Full-Load (Mechanical) Torque, $T_{(FL)}$, from (2.18):

$\mathbf{T_{(FL)}} = 15.47 - 1.21 = \mathbf{14.26\ N\text{-}m}$

j) Ratio of Full-Load (or Delivered) Torque to The Pull-Out Torque, $T_{(FL)}/T_{(PO)}$, from(2.6a,b):

$\tau_1 = 20.7/384.7 = 0.054$; $s_{fl} = 0.053$

$s_{(PO)} \approx (1 + 0.054)x7.3/\{20.7 + (1 + 0.054)x20.7\} = 0.18$; Thus,

$\mathbf{T_{(FL)}/T_{(PO)}} = 2/\{(0.053/0.18) + (0.18/0.053) = \mathbf{0.54}$

k) The Pull-Out (or Maximum) Torque, $T_{(PO)}$:

$\mathbf{T_{(PO)}} = T_{(FL)}/0.54 = \mathbf{1.85T_{(FL)}} = 1.85x14.26 = \mathbf{26.4\ N\text{-}m}$

l) Full-Load Efficiency, from(2.14): $\boldsymbol{\eta} = 2{,}112/(2{,}112 + 1055) = \mathbf{66.7\%}$

m) Full-Load (Output) Power Factor, from (2.7):

$$\mathbf{\cos\varphi_{rs}} = \frac{17.4 + 7.3/0.053}{\sqrt{\left[\left(17.4+7.3/0.053\right)^2 + \left(41.3\right)^2\right]}} = \mathbf{0.966\ Lagging}$$

n) Full-Load Input Power Factor:

$\mathbf{\cos\varphi_s} = \{2112 + 1055\}/3x380(5.4/\sqrt{3}) = \mathbf{0.89\ Lagging}$

p) Short-Circuit Power Factor, from (2.4b): $\mathbf{\cos\varphi_{sc}} = 720/\sqrt{3}x150x5.4 = \mathbf{0.5\ Lagging}$

4.5.2 Short-Circuit Current on Full Voltage($I_{sc(max)}$) from the Current/Slip Curve:

The value of this short-circuit current is clearly **14 Amps** on the curve being at a slip of unity. Based on this, we are able to further determine the following quantities:

q) Maximum Output Power, $P_{o(MAX)}$, from (2.4a), using phase current values as due:

$$\mathbf{P_{o(MAX)}} = 3x380x\frac{(14-1.2)/\sqrt{3}}{2(1+0.5)}x10^{-3} = \mathbf{2.8\ kW}$$

r) Ratio of Starting Torque to Delivered Full-Load Torque, $T_{(STT)}/T_{(FL)}$, from (2.19):

$\mathbf{T_{(ST)}/T_{(FL)}} = (14/4.2)^2 x\ 0.053 = \mathbf{0.59}$

4.6 Other Performance Curves generated through MATLAB:

4.6.1 Torque/Speed Characteristic Curve, from (2.5a):

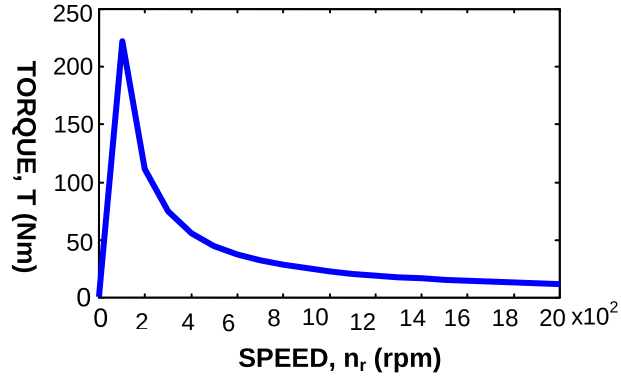

Fig.4.2: Torque/Speed Characteristic of the Test Motor

4.6.2 Power/Speed Characteristic Curve ,from (2.3):

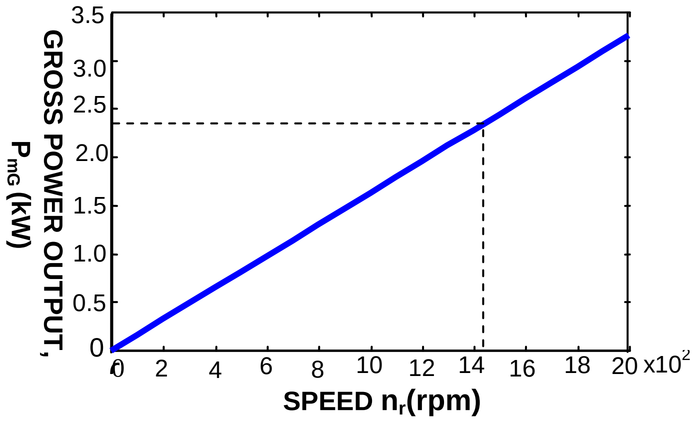

Fig.4.3: Gross Power Output/Speed Characteristic Curve

V. Analysis, Conclusion & Recommendation

5.1 Performance Analysis

For the purpose of easy analysis, a summary of the motor parameters obtained from calculations and performance curves shall first be presented as in Table 5.1 below.

Table 5.1: Summary of the Performance Parameters of the Test Motor

S/N	PARAMETER DESCRIPTION	VALUE OBTAINED	VALUE EXPECTED	REMARKS (On The Expected Values)
A	***LOSSES:***			
i)	Total Iron Losses	335W	122W	Typical for a 2.25kW 3-ph cage motor in [1]* p.465 and 3Hp (2.24kW) type in [2] p.147.
ii)	Total Copper Losses	720W	205W	As in [1]; whilst 210W (a close value) is the case in [2].
iii)	Total Machine Losses	1055W	327W	Being about 15% on 2.2kW.
B	***ACTIVE POWER:***			
i)	Net Output Power, $P_{o(NET)}$	2112W	2200W	Manufacturer's stated value.
ii)	Maximum Gross Output Power, $P_{o(MAX)}$.	1.3 $P_{o(NET)}$	2 – 2.5 $P_{o(NET)}$	As in [4] p.373; but a typical value in [1] p.468 is 1.92 $P_{o(NET)}$.
C	***EFFICIENCY:***			
	Full-Load Efficiency, η.	66.7%	83%	Typical for the motor in [2]; but not lower than 81% as in [3] p.60.
D	***POWER FACTORS:***			
i)	Full-Load Power Factor	0.966Lag	0.83Lag	Standard value as in [3] p.60.
ii)	Input Power Factor	0.89Lag	0.748Lag	Typical as in [1] p.466; whilst 0.785Lag is typical in [2] p.147.
E	***SLIPS:***			
i)	Full-Load Slip, s_{fl}.	5.3%	2 – 5%	Standard as in [4] p.370; but 2% in [1] and 3% in [2] are typical.
ii)	Pull-Out-Torque Slip, s_{po}.	0.18	0.12 – 0.2	Standard range as in [5] p.464.
F	***TORQUES:***			
i)	Full-Load Torque, $T_{(FL)}$	14.26N-m	11.39N-m**	Typical value as in [2] p.147.
ii)	Starting Torque, $T_{(ST)}$	0.59 $T_{(FL)}$.	1.15 – 1.5$T_{(FL)}$	Standard range as in [2] p.386.
iii)	Pull-Out Torque, $T_{(PO)}$	1.85$T_{(FL)}$	1.6 – 2.5$T_{(FL)}$	Standard range as in [5] p.482.
G	***SPEED:***			
	Full-Load Rotor Speed, n_r	1,420.5rpm	1,420rpm	Manufacturer's stated value.
H	***RESISTANCES:***			
i)	Stator Resistance, R_s	17.4Ω	1.46Ω	Typical value as in [1] p.469.
ii)	Rotor Resistance, R_{rs}	7.3Ω	0.8R_s (at least)	0.8425R_s = 1.23Ω used in [1].
I	***REACTANCES:***			
i)	Stator/Rotor Reactances	20.7Ω (each)	8.1Ω (each)	Combined value = 16.2Ω in [1].
ii)	Magnetizing Reactance	384.7Ω	347Ω	Typical value as in [1] p.469.

* ***Table References:*** [1] Shepherd et.al.; [2] Liwschitch-Garic & Whipple; [3] Boehle et. al.; [4] Mittle & Mittal; [5] Kostenko & Piotrovsky; [6] Krause P.C.

** ***Torque Units Conversion:*** 8.4Ib-ft = 8.4x1.356534 = 11.39N-m.

5.1.1 Starting Performance:

It is obvious from item F(ii) in Table 5.1 that the test machine has a weak starting performance; meaning an inability to start from rest with the full load applied to it, even under direct-on-line starting condition with the stator winding connected in delta.

5.1.2 Running Performance:

The machine is seen to have an excellent normal running capability judging from the value of the full-load torque which on the rated speed is 125% of the expected value. Also, a very good overload capacity which stands at 1.85 is observed; implying that it cannot easily get stalled on reasonable values of overload.

5.1.3 Efficiency:

The efficiency on full load is quite poor. This follows the fact that the machine total amount of losses is approximately 245% of the value (430W) appropriate for the acceptable efficiency of 83% on 2112W output. The principal contributory factor is the outrageous value of the stator resistance being roughly 12 times the expected value; meaning that the winding turns per phase is too high and/or the copper wire gauge too small.

5.2 Conclusion & Recommendation

Although the objective of refurbishing the motor to exhibit satisfactory running torques, power factors, slips and speeds was achieved the machine, however, is seen to develop too much heat in the process for a continuous full-load operational duty (i.e. on CMR duty). It is therefore recommended that the motor should be installed and used where it shall be required to render ***intermittent services only*** (e.g. as a grinding or drilling machine drive).

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