DESIGN OF THREE PHASE INDUCTION MOTOR FOR SUBMERSIBLE PUMP TO RUN UNDER WIDE RANGE OF VOLTAGE

PROJECT REPORT
Submitted by

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1999 - 2000

in partial fulfillment of the requirement of the award of the Degree of Bachelor of Engineering in Electrical and Electronics Engineering of the Bharathiar University.

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Kumaraguru College of Technology
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CERTIFICATE

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Department of Electrical and Electronics Engineering

CERTIFICATE

This is to certify that the report entitled

DESIGN OF THREE PHASE INDUCTION MOTOR
FOR SUBMERESIBLE PUMPS
TO RUN UNDER WIDE RANGE OF VOLTAGE.

has been submitted by

Mr. S. Sajeesh, M. PrabhuAnandan, S. Anand,
T. Sivakumar

In partial fulfillment for the award of the Degree of Bachelor of Engineering in the Electrical and Electronics Engineering Branch of the Bharathiyar University, Coimbatore - 641 046 during the academic year 1999 - 2000.

Guide 11/2/2000

Date

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Internal Examiner

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CERTIFICATE

This is to inform to whomsoever it may concern that the following final year students,

S.Sajeesh

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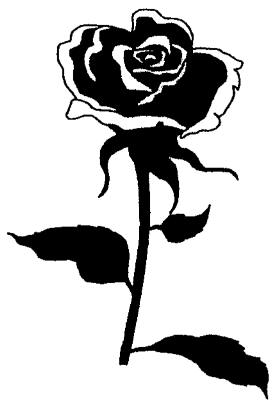
T.SivaKumar

of Kumaraguru College of Technology, have completed the project title **" Design of Three phase Induction motor for Submersible pumps to run under wide range of voltage"**, with the active involvement of our company.

The motor designed and fabricated by them is working satisfactorily and also meets the design specification.

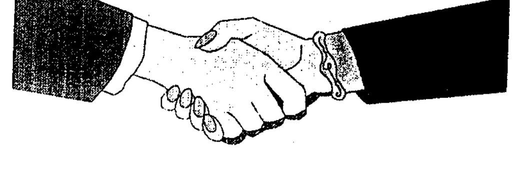
For DECCAN INDUSTRIES



Dedicated

To our

Beloved parents



ACKNOWLEDGEMENT

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We are very much thankful to our beloved Professor and Head of the Department, **Dr.K.A.Palaniswamy, B.E.,M.Sc.(Engg), Ph.D., C.Eng(I), M.I.S.T.E., F.I.E.,** for his encouragement.

We also thank our Principal **Dr.K.K.Padmanabhan, B.Sc(Engg), M.Tech., Ph.D.,** for his patronage.

Our sincere thanks are due to Mr. **K.K.Veluswamy**, Managing Director, DECCAN INDUSTRIES, who spared his precious time in helping us through out this project. We also thank him for having sponsored this project.

We also express our thanks to the workers of DECCAN INDUSTRIES who helped us in manufacturing the motor.

SYNOPSIS

SYNOPSIS

This project deals with the design and manufacture of an induction motor for a submersible pump, which can withstand variation of voltages and give the same output even under reduced voltage.

The design is of that of an ordinary induction motor. After the design is complete, an analysis of the equivalent circuit of the motor is made, from which the capacity of the motor to withstand the fluctuation is estimated. When the voltage reduces, the magnetizing reactance increases, the resistance decreases and as a result, the no load current also decreases. The motor develops the constant power depending on the rating of the pump. So the slip increases to supply the constant power. The slip, at which the power is same as that of the specified value, is noted. If this slip remains in the variable limit, then the motor withstands the fluctuating voltage. The slip is varied and by an iterative procedure, the slip at which the constant power is developed is noted.

The motor is fabricated and the pump is coupled to the shaft of the motor. The discharge of the pump is then checked under reduced voltage.

CONTENTS

INTRODUCTION

CHAPTER I

INTRODUCTION

Today's agricultural field faces a major problem of voltage fluctuation. The voltage does not remain constant throughout the day. It is seen that the voltage varies in a very large range. The supply from a three phase system does not always provide 415 volts. Due to this voltage variations, the performance of the motor is affected. So there is a need for a motor for a submersible pump to give the same discharge even when the voltage goes below the rated value.

The motors generally used for the submersible pumps are induction motors. The induction motors are preferred because of their robust construction.

There are two types of induction motor based on the construction of the rotor.

1. Squirrel Cage rotor
2. Wound rotor

Cage rotor consists of the rotor bars inserted into the slots. This type of construction offers rigidity to the motor. This type of motor does not allow any addition of extra resistance to the rotor. Most of the motors involve this kind of construction.

Wound rotors consists of windings housed in the slots. They provide the facility of adding extra resistance to the rotor circuit.

Most of the motors use the squirrel cage construction because of the robust construction. Almost all applications use the cage rotor for the induction motor.

1.2 Advantages of Induction motor :

Of all the types of motor available, the induction motor is widely used and can be built in any size from a few watts up to several thousand kW. It has the following advantages :

- ☞ Its cost is low and is very reliable.
- ☞ It has sufficiently high efficiency.
- ☞ It has good power factor.
- ☞ It has a very simple and extremely rugged construction.
- ☞ In normal operating conditions no brushes are needed; hence frictional losses are reduced.
- ☞ It requires minimum of maintenance.
- ☞ It starts from rest and needs no extra starting motor and has not to be synchronized.
- ☞ Its starting arrangement is simple especially for squirrel cage type motor.

1.3 Applications

- Slip ring induction motors are used in paper mills to give speed less than 200 rpm for beaters and large starting torque.
- Slip ring induction motor are used.In fan drives
- Compressors make use of induction motors.
- High torque squirrel cage induction motors are used in textile mills
- Slip ring induction motors are used in coal mines for the drives used for compressor fans, pumps, conveyors and hoists.
- For high grinding spindles for horological applications, drilling of PCBs etc., make use of high frequency three phase induction motors.
- Squirrel cage motors are used in centrifugal pumps.
- Stirrers in chemical industry also make use of slip ring induction motors.
- Induction motor is used as prime mover in Ward Leonard system.

All these applications of the induction motor are due to its robust construction and reliability.

CONSTRUCTIONAL DETAILS

CHAPTER II

CONSTRUCTIONAL DETAILS OF INDUCTION MOTOR FOR SUBMERSIBLE PUMPS

The two main parts of the induction motor are

1. Stator
2. Rotor

2.1 STATOR

Stator is the stationary part of the induction motor. It is cylindrical structure made of dynamo grade laminations. Motor having outside diameter of the stator core up to about one meter use one-piece core lamination.

For large sized motors the stator cores are made of segmental laminations. This is done in order to avoid wasting of steel from the center of the rotor and from the outside corner of the stator with the cores made up of segments assembled in ring form. For quick assembly of stator core, maximum chord of segment should not be less than 0.37 m. It is necessary to determine the location and the number of dovetails per segment.

2.2 STATOR FRAME

Frames of electrical machines are structures in which stator cores are assembled. They serve four distinct purposes :

- They enclose the core and windings.
- They shield the live and moving machine parts from human contact and from injury caused by introducing objects or weather exposure.
- They transmit the torque to the machine supports and are therefore designed to withstand twisting forces and shocks.
- They serve as ventilating housing or means of guiding the coolant into effective channels.

The Stator consists of the windings to which the supply is given. The stator also forms the mechanical support for the machine. It consists of slots in which the windings are housed. The slots may be semi-closed type or open type. The stator stamping iis shown iin fig. 2.1.

2.3 STATOR WINDINGS :

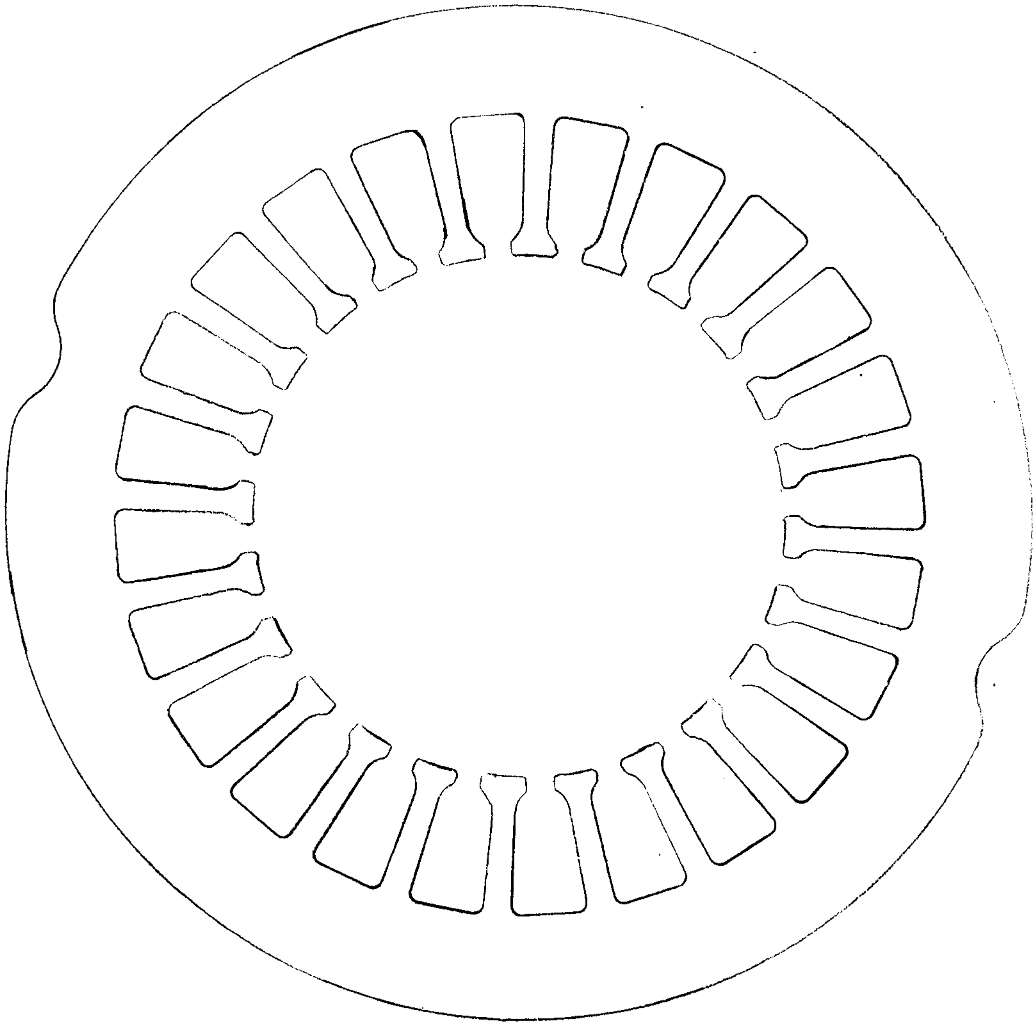
The windings used are copper conductors insulated with PVC coating. The PVC coating gives the necessary insulation from water. The windings are arranged concentrically in the slots, with half of the conductors in the slot branching in two opposite directions. The three phases of the windings may be connected in star or delta fashion. The squirrel cage motors are usually started using the star-delta starters and therefore are designed for delta connection.

For induction motors, the frame should be strong and rigid, both during construction and after assembly of the machine. This is because the length of the air gap is very small and if the frame is not rigid, the rotor will not remain concentric with the stator, giving rise to unbalanced magnetic pull. The winding diagram is shown in fig. 2.3. The delta connected winding is shown in fig. 2.4.

The frames of large sized machines are fabricated by welding steel plates. The advantage of fabrication is its adaptability to new designs and modifications. Frames of small machines are made as a single unit. The frames of totally enclosed machines are provided with axial fins in order to increase the heat dissipating surface.

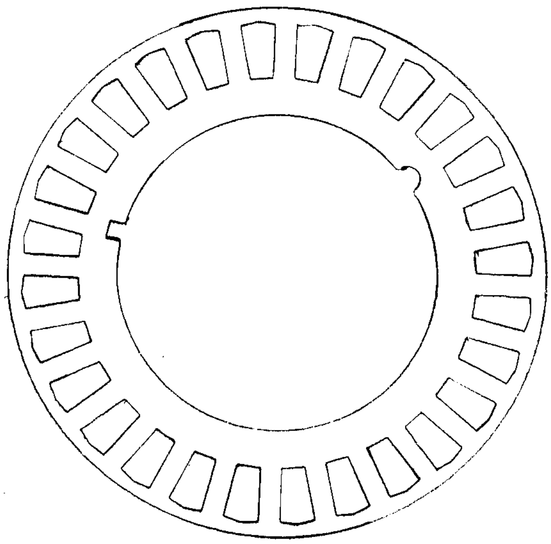
2.4 ROTOR :

Like Stator, the rotor laminations are punched as a single unit in the case of small machines while in large machines the laminations are segmented. The rotor cores of small machines are often put on the shaft directly and keyed to it for transfer of torque. In order to provide paths for ventilating air, radial and axial ducts are used. The number of radial ventilating ducts provided in the rotor is equal to that in the stator. The segmental laminations are fixed to rotor spider. This comprises of a shaft with arms and stiffeners. The rotor stamping is shown in fig. 2.2.



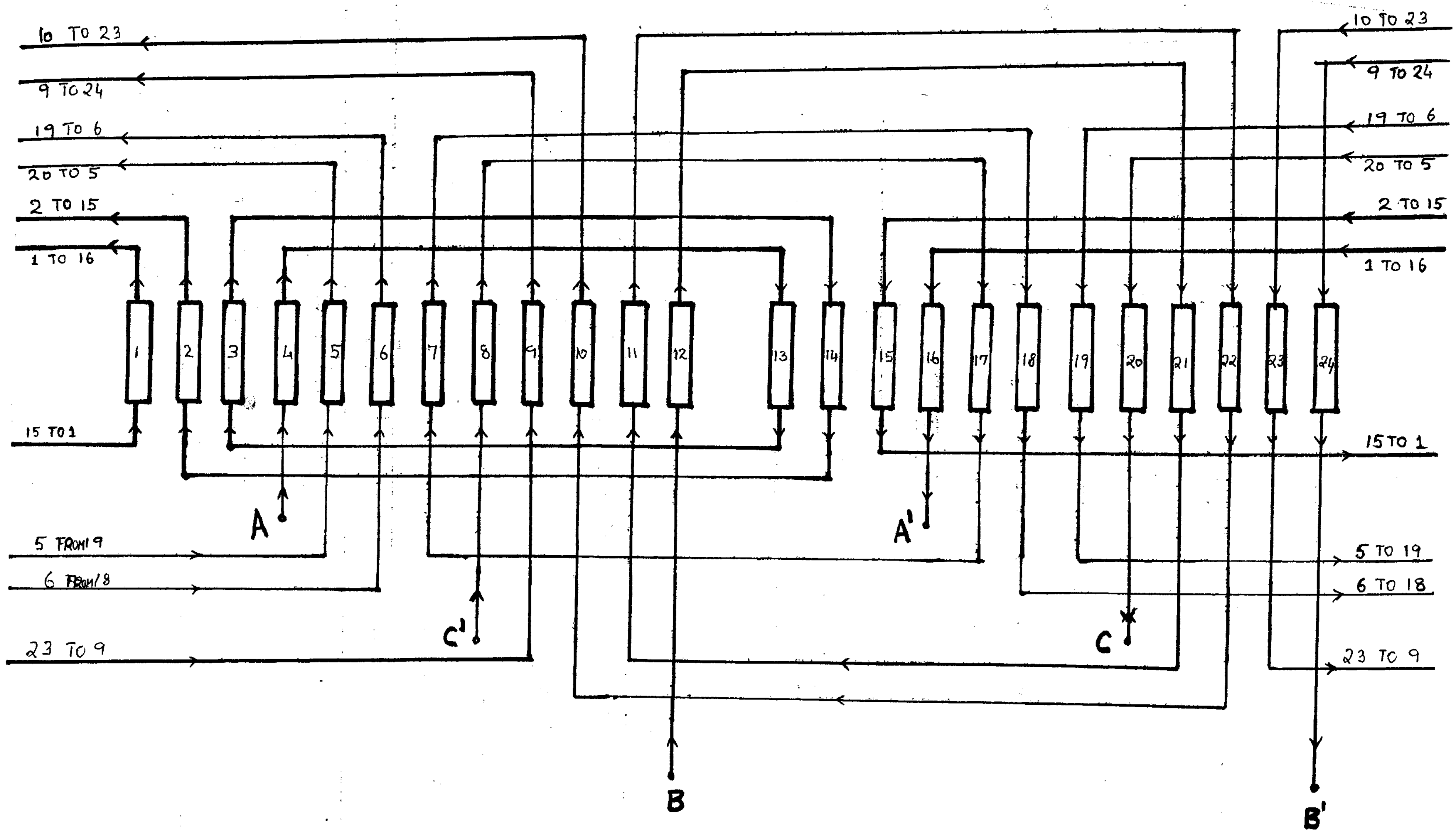
STATOR STAMPING

FIG. 2.1



ROTOR STAMPING

Fig. 2.2



10 TO 23
9 TO 24
19 TO 6
20 TO 5
2 TO 15
1 TO 16
15 TO 1
5 FROM 9
6 FROM 18
23 TO 9
1
2
3
4
5
6
7
8
9
10
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12
13
14
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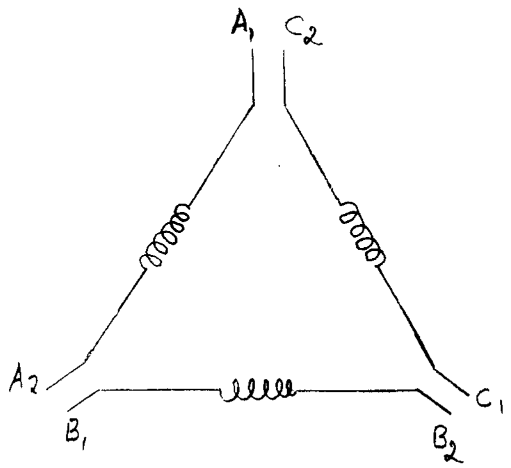
16
17
18
19
20
21
22
23
24
A
A'
B
B'
C
C'
10 TO 23
9 TO 24
19 TO 6
20 TO 5
2 TO 15
1 TO 16
15 TO 1
5 TO 19
6 TO 18
23 TO 9



DELTA CONNECTED STATOR WINDING

FIG. 2.4

DESIGN CONSIDERATIONS

- Tooth pulsation loss :

Tooth pulsation losses and noise can be minimized by using large number of narrow slots.

- Leakage reactance :

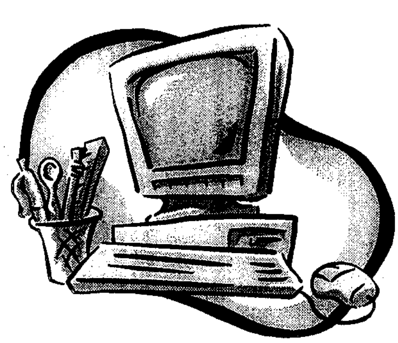
If there are large number of slots, the insulation increases and as a result the width of the insulation increases. Leakage flux has a long path, resulting in the reduction of leakage reactance.

- Ventilation :

The larger the number of slots, the smaller will be the slot pitch. If the slot pitch is small, the tooth pitch is also small. This makes the tooth smaller and mechanically weak. So they are supported at the radial ventilating ducts by welding T or I sections. This obstructs the flow of air in the ducts, there by impairing the cooling.

- Magnetizing current and Iron loss :

The use of larger number of slots may result in excessive flux density in teeth giving rise to higher magnetizing current and higher iron loss.



DESIGN

CHAPTER IV

DESIGN OF THE INDUCTION MOTOR

4.1 SPECIFICATION OF THE MOTOR

Power output (P)	:	10 hp (7.5 Kw)
Rated voltage (V)	:	380 volts
Frequency (f)	:	50 Hz
Speed (N)	:	3000 rpm
Power factor (pf)	:	0.8
Efficiency (η)	:	0.79
Number of poles (p)	:	2
Rotor	:	Cage rotor
Fluctuation allowed	:	- 30 % to +5 %
Winding factor (K_w)	:	0.955 (assumed)
Stamping material	:	Silicon Steel

$$\text{Power output} = 10 \text{ hp} = 7.46 \text{ kW}$$

$$\text{kVA rating} = \frac{\text{Power}}{\text{Power factor x efficiency}}$$

$$= \frac{7.46}{0.8 \times 0.79} = 11.804 \text{ KVA}$$

$C_0 = 1.1\,\pi^2 K_w B_{av}\, q\, 10^{-3}$

$= 1.1 * 0.955 * 0.4 * 30000 * 10^{-3}$

$= 126.06$

poles = 2

Speed in rps, n = $\dfrac{120 * f}{p * 60}$

n = $\dfrac{120 * 50}{2 * 60}$ = 50 rps

kVA Rating, Q = $C_0 D^2 L n$

11.804 = $126.06 * D^2L * 50$

D^2L = $0.00187\ m^3$

Choosing D as 72 mm, the value of L is found.

Diameter, D = 72 mm

Core length, L = 361 mm

Turns Per Phase

Flux per pole, $\Phi = B_{av} L \tau$

Pole pitch, $\tau = \dfrac{\pi D}{p}$

$= \dfrac{\pi (0.72)}{2} = 113.1$ mm

Flux per pole, $\Phi = 0.4 * 0.361 * 0.1131$

$= 16.33$ m.wb

Stator turns per phase, Ts $= \dfrac{Es}{4.44 * f * \Phi * K_w}$

$= \dfrac{380}{4.44 * 50 * 16.33 * 10^{-3} * 0.955}$

$= 109.76 \cong 110$ Turns per phase

Full load current, I_1

$= \dfrac{Q}{3\ Es} = \dfrac{11.804 \times 10^3}{3 \times 380} = 10.35$ A

Choosing a current density $\delta = 10\ A/mm^2$

Area $= 10.35 / 10$
$= 1.035$ mm

diameter d = 1.15 mm

Conductor diameter including the PVC insulation

Diameter d = 1.85mm

Area required for conductor in the slots

= No. of slots * d^2 * $\pi/4$

= $28 \times (1.85)^2 \times (\pi/4)$ = 75. 26 mm^2

Mean length of conductor

= $[L + 1.15(\tau) + 120]$

= $360 + 1.15(\pi \times 72/2) + 120$

= 610 mm

Length of the conductor per phase

= 2 x 110 x 0.61

= 134.42 m

STATOR SLOT

Choosing a semi-closed slot for the stator :

Slot pitch, y_{ss} = 9.45 mm

Slot width at the bottom, Ws_1 = 7 mm

Slot width at the top, Ws_2 = 10 mm

Trapezoidal area = 0.5 x Height x [sum of the parallel

sides]

= 0.5 x 17 x [10 +7]

= [illegible]

Area required for the conductors = [illegible]

% Of slot occupied by the winding = [illegible]

= [illegible]

ROTOR SLOT

A closed slot is chosen for the rotor slot :

$$\text{Slot pitch} = \frac{\pi D}{Sr} = \frac{\pi (70.8)}{28} = 7.94 \text{ mm}$$

Area of the rotor bar

Tapezoidal area = 0.5 x Height x [sum of the parallel sides]

= (3.3 + 4.8) (7.8)(0.5) = 31.59 sq mm

Triangular area = 0.5(b)(h)

= 0.5(0.3) (0.3) = 0.045 sq mm

Total area = 31.635 sq mm

Taking a current density δ = 6 A/ sq mm

Bar current = 31.635 x 6 = 189.81 A

Depth of the stator core

= $(0.5)[D_0 - D - 2(\text{depth})]$

= (0.5)[137.9 – 72 – 2(18.5)]

= 14.45 mm

Mean diameter of the core

= D + Depth of slot (2) + Depth of core

= 72 + 18.5(2) + 14.45

= 123.45 mm

Area of the core = L * Depth of core * stamping factor

= 360 * 14.45 * 0.92

= 4785.84 sq.mm

Flux density in the core

$$= \frac{16.33 \times 10^{-3}}{2\,(4785.84) \times 10^{-6}}$$

= 1.706 wb/m^2

At 1.706 wb / m^2 , the at/m = 320 and loss = 3.3 W/ kg.

Total Amp.Turns = $320 \times 194 \times 10^{-3}$

= 62.080 AT

Weight of the core = $\pi/4\ [(\text{Outer dia})^2 - (\text{inner dia})^2\ ] * L * 0.92 * d$

= $\pi/4[(137.9)^2 - (90.5)^2]\ 360 \times 0.92 \times 7.78 \times 10^{-6}$

= 22.09 kg.

Iron Loss = Loss/kg * weight

= 3.3 x 22.09

= 72.9 watts.

Diameter at the lower part of the slot

= 72 + 2(3.5)

= 79 mm

Tooth pitch = $\pi(79)/24$ = 10.34 mm

Tooth width = 10.34 – 7 = 3.34 mm

Diameter at the top of the slot

= 72 + 2(18.5)

= 109 mm

Tooth pitch = $\pi(109)/24$ = 14.268 mm

Tooth width = 14.268 – 10 = 4.268 mm

Taking average tooth width as 3.8 mm

$$\text{Flux density in the teeth} = \frac{\text{flux per pole}}{\text{Area of teeth} * L * \text{Stamping factor}}$$

$$= \frac{16.33 \times 10^{-3}}{12 \times 360 \times 3.8 \times 0.92 \times 10^{-6}}$$

$= 1.081 \text{ wb / m}^2$

Total flux density B_t = $1.081 \times \cos 30$

$= 1.47 \text{ wb/m}^2$

At 1.47 wb/m^2 at/m =55 and loss = 3.3 W/kg.

AT in the teeth = $55 \times 18.5 \times 10^{-3}$ AT

= 1.0175 AT

Weight of the teeth = S * L * depth * mean width

= 24 x (0.0185) x (0.36) x (3.8 x 10^{-3}) x 0.92

x 7.78 x 1000

= 4.347 kg.

Loss in the teeth = loss/kg * weight

= 4.347 x 3.3

= 14.34 watts.

Total loss in the stator = 72.90 + 14.34 = 87.24 watts.

ROTOR CORE

Depth of the rotor core

Diameter of the rotor = 70.8 mm

Depth of the slot = 8.5 mm

Depth of the rotor core = (0.5)[70.8 – 2(1) – 43.5 – 2(8.5)]

= 4.15 mm

Mean dia of the rotor core = 4.15 + 43.5 = 47.45 mm

Mean length of the magnetic path in the rotor core

= π(47.45)/2 = 74.85 mm

Rotor core flux density = $\dfrac{16.33 \times 10^{-3}}{2(4.15 + 43.5)\ 360 \times 0.92 \times 10^{-6}}$

= 0.52 wb / m^2

Total flux density = 0.52 x 1.36

= 0.7072 wb /m^2

From the fig. 3.1

At this flux density AT/m = 10

AT in the rotor core = 10 x 74.85 x 10^{-3}

= 0.7485

ROTOR TOOTH

2/3 of rotor depth = 2/3(8.5) = 5.67 mm

Dia at 1/3 distance of the slot

= [70.8 – 2 – (2)5.67]

= 57.46 mm

Pitch of the rotor teeth = π(57.46) / 28 = 6.45 mm

Width at 1/3 distance = 6.45 – 3.5 = 2.95 mm

Rotor tooth density (1/3) = $\dfrac{16.33 \times 10^{-3}}{14 \times 360 \times 0.92 \times 10^{-6} \times 2.95}$

= 1.194 wb/m^2

Total flux density = 1.36×1.194

= 1.62 wb/m^2

From the fig. 3.1.

At this flux density, AT/m = 140

AT in the rotor tooth = $140 \times 8.5 \times 10^{-3}$

= 1.19 AT

AIR GAP

Air gap length = 0.6 mm

Air gap area = $\pi(72) \times 360/2$ = 0.04071 m^2

Opening of stator slot = 4 mm

Width / lg = 4/0.6 = 6.67

For this ratio

$k_1 = 0.68$

$$Kg_1 = \frac{\text{Slot pitch}}{\text{Slot pitch} - 3(k_1)} = \frac{9.425}{9.425 - 0.68(3)}$$

= 1.276

kg_2 = 1

Effective air gap = $0.6 \times 10^{-3} \times 1.276 \times 1$

= 0.7656×10^{-3} m

Flux density in air gap = $\frac{1.36 \times 16.33 \times 10\text{-}3}{0.04071}$

= $0.5455\ wb/m^2$

AT in air = B_a * Effective air gap * 0.8 * 10^6

= $0.5455 \times 0.7656 \times 10^{-3} \times 0.8 \times 10^{-6}$

= 334.107 AT

Total AT for magnetic circuit

Stator teeth	=	1.0175 AT
Stator core	=	52.75 AT
Air gap	=	334.107 AT
Rotor teeth	=	0.7485 AT
Rotor core	=	1.19 AT
Total	=	390 Amp.Turns

Magnetising Current

$$Im = \frac{p \times AT}{2.34\times 0.955 \times Turns/phase}$$

$$= \frac{2 \times 390}{2.34 \times 0.955 \times 110}$$

= 3.17 Amp.

Core Current loss

Ic = Loss/(3 x Voltage)

$$= \frac{87.24 + 98}{3 \times 380}$$

$= 0.1625$ A

Magnetizing Reactance

$= 380/3.17 = 120\ \Omega$

Resistance $= 380/0.1625 = 2338\ \Omega$

No load current $= [(3.17)^2 + (0.1625)^2]^{1/2}$

$= 3.174$ A

No load power factor $= \text{Cos}\ \varphi_0$

$= 0.1625/3.17$

$= 0.051$

End ring current

$I = I_b\, g_2 / \pi$

$= 189.8 \times 14/\pi$

$= 845.8$ A

Mean dia of end ring $= 57$ mm

Area of end ring $= 300\ mm^2$

Resistance of end ring

$$= \frac{0.34 \times \pi(57) \times 10^{-3}}{300}$$

$= 0.020 \times 10^{-3}\ \Omega$

Loss in End rings	=	$2 \times (845.8)^2 \times 0.020 \times 10^{-3}$		
	=	29.11 watts.		
Loss in rotor bars	=	28 x 189.8		
	=	267.85 watts.		
Total copper loss	=	267.85 + 29.11	=	297 watts.
Rotor input	=	7500 + 297	=	7797 watts.
Slip	=	297 / 7797	=	3.81 %
$3 (I`_2)^2 r`_2$	=	297		
$\Rightarrow r`_2$	=	1.44 Ω		
Total losses	=	336.96 98.00 185.24 297.00		
Total losses	=	916.5 watts.		

$$\text{Efficiency} = \frac{7500}{7500 + 916.5} = 89.11\ \%$$

Rotor slot permeance

$$= \frac{8}{3 \times 3.5} + \frac{2(1.5)}{3.5}$$

$$= 1.62$$

refered to stator $= \frac{1.62 \times (0.955)^2 \times 24}{28}$

Slot leakage permeance $= 1.55 + 1.267 = 2.817$

Slot leakage reactance

$$= \frac{31.6 \times 10^{-6} \times 50 \times 110^2 \times 0.36(2.817)}{4 \times 3}$$

$$= 1.61$$

Overhang leakage

$$= L_0 \lambda_0$$

$$= k_s Y^2/(\pi \times y_{ss})$$

$$= \frac{0.9 \times 0.1131}{\pi \times 9.425 \times 10^{-3}}$$

$$= 0.389$$

$$X_0 = \frac{31.6 \times 10^{-6} \times 50 \times (110)^2 \times 0.389}{4 \times 3}$$

$$= 0.62\ \Omega$$

$X_Z = 5/6 \times 120[(1/12)^2 + (1/14)^2]$

$= 1.2046\ \Omega$

Reactance per phase

$X_1 = X_Z + X_0 + X_s$

$= 1.2046 + 0.62 + 1.61$

$= 3.4346\ \Omega$

Stator winding resistance, $r_1 = 1.0485\ \Omega$

Reactance, $X_1 = 3.4346\ \Omega$

$R_m = 2338\ \Omega$

Magnetizing resistance, $X_m = 120\ \Omega$

$$I_1 = \frac{380}{3.4346 + 1.0485 + [1.44(1-s)/s]}$$

$I'_2 \cong I_1$

Power developed $= 3\,(I'_2)^2 R_L$

$R_L = (r'_2 / s)$

After a number of iterations, the slip, at which the power developed is 7.5 kW , is found to be

$s = 0.029$

The equivalent circuit is shown n fig. 4.1.

To find the slip at which the motor delivers the specified power

To find the slip during reduced voltage condition

$$V_{ph} = 4.44 * f * \varphi * K_w * \text{Turns /phase}$$

$$266 = 4.44 * 50 * \varphi * 0.955 * 110$$

$$\Rightarrow \varphi = 11.4 \text{ m.wb.}$$

Under such flux per pole, the flux densities in the stator and the rotor are

Flux density in the stator core = 1.192 wb / m^2

Flux density in the rotor core = 0.5 wb / m^2

Flux density in the air gap = 0.381 wb / m^2

Flux density in the stator teeth = 1.027 wb / m^2

Flux density in the rotor teeth = 1.134 wb / m^2

The ampere turns required are

Stator core	4.656 AT
Stator teeth	0.3145 AT
Air gap	233.35 AT
Rotor core	0.6137 AT
Rotor teeth	0.2975 aT
Total	240 Amp.Turns

Magnetizing current

$$I_m = \frac{2 \times 240}{2.34 \times 0.955 \times 110}$$

$$= 1.952 \text{ Amp}$$

$$\text{Loss} = 49.7 + 9.78 = 59.5 \text{ watts}$$

$$\text{Core loss current} = \frac{59.5 + 98}{3 \times 266}$$

$$= 0.1974 \text{ Amp.}$$

Reduction in voltage

$$= 30\ \%$$

$$\text{Reduced voltage} = 380 - [\,(0.3)\ 380\,] = 266 \text{ volts}$$

Magnetizing reactance

= Voltage / magnetizing current

$$= \frac{266}{1.952}$$

$$= 136\ \Omega$$

Resistance = Voltage / Core loss current

$$= \frac{266}{0.1974}$$

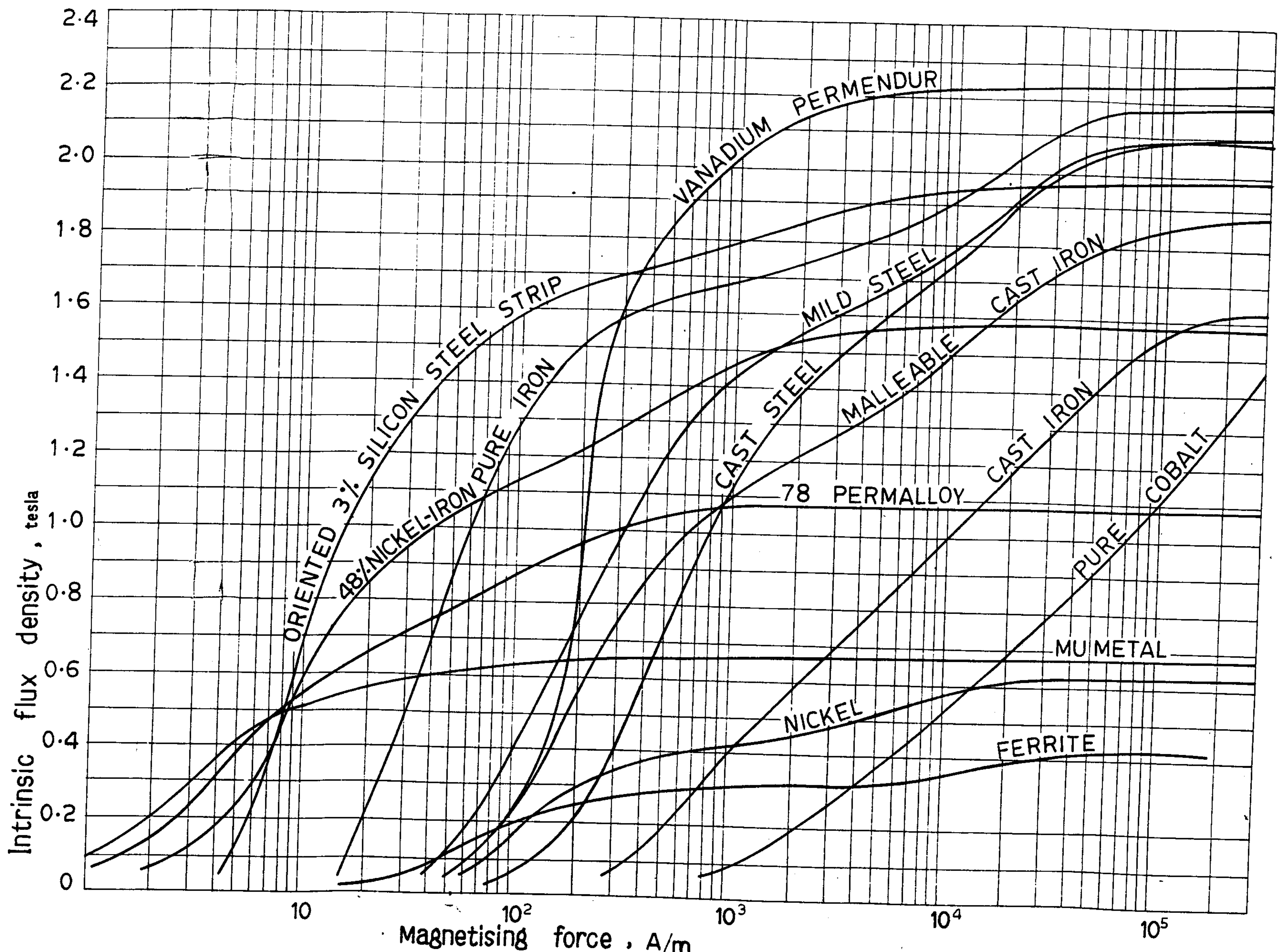
$$= 1347\ \Omega$$

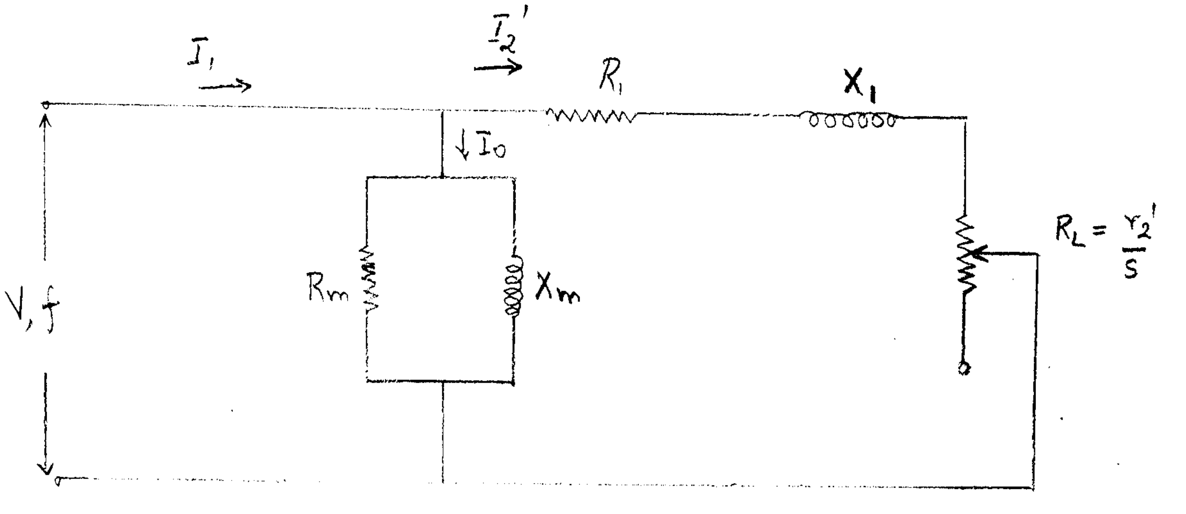
$$I_1 = \frac{266}{3.4346 + 1.0485 + [\ 1.44\ (1\text{-}s)/s]}$$

The slip at which the specified power (7.5 kW) is developed, is found to be

$$s = 0.074$$

Thus the motor develops the same output at a slip of 0.074, under reduced voltage. This shows that the motor is capable of withstanding the variation in voltage.


Intrinsic flux density, tesla
0
0·2
0·4
0·6
0·8
1·0
1·2
1·4
1·6
1·8
2·0
2·2
2·4
Magnetising force, A/m
10
10^2
10^3
10^4
10^5
VANADIUM PERMENDUR
ORIENTED 3% SILICON STEEL STRIP
48% NICKEL-IRON
PURE IRON
MILD STEEL
CAST STEEL
CAST IRON
MALLEABLE CAST IRON
78 PERMALLOY
PURE COBALT
MU METAL
NICKEL
FERRITE



EQUIVALENT CIRCUIT

Fig. 3.2

CONCLUSION

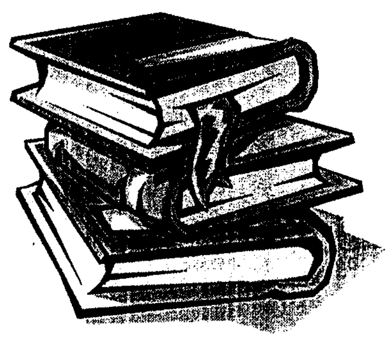
CHAPTER V

CONCLUSION

- A 10 hp, 380 volts, 50 Hz, 3phase, squirrel cage motor for the submersible pump has been designed and fabricated. The motor was coupled to the pump and the discharge has been noted. The pump was found to give specified discharge even under reduced voltage. The motor was found to develop 7.5 kw even under reduced voltage. Thus the fluctuation limit of -30 % to +5 % is achieved.

The slip, at which the specified power is developed is noted and is found to be in the variable limit.

The submersible pump finds its application in the agricultural field, for irrigation purposes.



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