

Design of three Phase Induction Motor using Mat Lab Programming

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Abstract:- The basic design of induction motors has not changed in the last 40-50 years, with latest and good insulation materials, design is based on computer optimization techniques and using automated manufacturing methods have resulted in motors of smaller physical size and cost per kW is less. The standards set by International of physical dimensions and frame sizes means that motors from most manufacturers are physically interchangeable and they have similar performance characteristics.

But to design the calculation manually for the induction motor is time consuming and very difficult to get the accurate value. For construction of induction motor the values must be accurate, so by using the mat lab programming the calculation becomes very simple and the time taken will be less with accurate values.

Keywords:- induction motor, mat lab

NOMENCLATURE:

P_h	No of phases
P	Power in KW
v	Voltage in volts
f	Frequency in Hz
p_o	No of poles
B_{av}	Flux density in wb/m ²
q	Ampere conductor in A/m
Co	Output co-efficient
D	Diameter of core in meters
Li	Net length of the core in meters
T_p	Turns per phase
q_s	Stator slots per phase
s_s	Stator slots
K_{ws}	Stator winding factor
I_s	Stator current per phase in amps
A	Area of stator in meters
W_{ts}	Width of stator teeth in meters
L_{mts}	Length of mean turn in meters
B_{mst}	Flux density in stator teeth wb/m ²
A_{sc}	Area of stator core in M ²
D_{cs}	Depth of stator core in meters
B_{cs}	Flux density in stator core wb/m ²
D_{ss}	Depth of slot in meters
D_o	Outside diameter of stator lamination in meters
L_g	Length of air gap in meters of rotor
D_r	Diameter of the rotor in meters
Y_{sr}	Rotor slot pitch
I_b	Rotor bar current in amps
A_b	Area of rotor bar in m ²
R_b	Resistance of each bar in ohms
T_{clb}	Total copper losses in bars in watts
I_{be}	End ring current in amps
A_e	Area of end ring in m ²
D_{oer}	Outer diameter of end ring in meters
D_{ier}	Inner diameter of end ring in meters
R_e	Resistance of end ring in ohms
C_l	Copper losses in end ring in watts
T_{cl}	Totoal rotor copper losses in watts

S	Slip of rotor
D_i	Inner diameter of rotor
K_{gss}	Gap concentration factor for stator slots
K_{gsr}	Gap concentration factor for rotor slots
A_g	Area of air gap in m ²
L_{ge}	Effective length of air gap in meters
A_{tg}	Mmf of air gap in amps
A_{tp}	Area of teeth per pole in m ²
$MMFST$	Mmf required for stator teeth in amps
A_{cs}	Area of stator core in m ²
L_{cs}	Length of magnetic path through stator core in meters
A_{tes}	MMF required for stator core in amps
A_{tr}	Area of teeth per pole in m ²
B_{tr}	Flux density in rotor teeth in wb/m ²
A_{trt}	MMF required for rotor teeth in amps
A_{cr}	Rotor core area in m ²
L_{cr}	Length of flux path in rotor core in meters
A_{ter}	MMF for rotor core in amps
I_m	Magnetizing current per phase in amps
W_{st}	Weight of stator teeth in kg
I_{lst}	Iron loss in stator teeth in watts
W_{sc}	Weight of stator core in kg
I_{lsc}	Iron loss in stator core in watts
I_l	Total iron loss in watts
I_{tl}	Total actual iron losses in watts
F_{wl}	Friction and windage loss in watts
T_{nll}	Total no load losses in watts
I_l	No load current per phase in amps
I_0	No load current in amps
P_{f0}	No load power factor
Eff_1	Efficiency at full load
R_s	Resistance of stator winding in ohms

Introduction:

As we know that for many industrial and mining applications, 3-phase induction motor plays a major role.

Induction motor can be operated directly or by using a variable drives. In developed and many industrialized countries the electrical energy is converted in mechanical energy by using the induction motors. The application of these motors are used in all stage of manufacturing and processing and also it is used in commercial and domestic applications. It is very popular, when we consider the simple design, low cost, high efficiency [8].

A poly phase induction motor consists of two major parts, the stator and rotor. The construction of each one is basically a laminated core provided with slots for winding. When one of the winding is excited with an ac voltage a rotating field is set up.

To design the 3 phase induction motor of the stator, rotor, end rings, and main parts of the induction motor is very difficult by using the manual calculation or software. The design of the induction motors is been well established, there are some areas which require special care. The manual design is been a lengthy calculation and if any change in the parameters needs to be recalculated. This results in the time and effort is required by the designer to do the calculations accurately [8].

As an example, after doing the calculations of an Induction motor design it is observed that performance of the machine is not satisfactory and dimension of the machine is uneconomical. To solve this, the designer has to change some design parameters like electric loading, magnetic loading, insulation thickness etc. Hence iterative calculation of the entire design procedure is required to achieve a satisfactory result. The approximations assumed in the manual calculations also lead to inaccurate results. As they are many software's to design as Computer aided design excel .so that the essential suitably program is required for the optimum design. The design features of an induction motor are classified as constructional wise and performance wise and the results are tabulated. The design software which is been used in manufacturing of the motors are very expensive and owned by companies who cannot disclose the details of it. So the demand and requirement of design software for educational purpose is on the rise [8].

So, by using the mat lab programming we can get the exact values of the design for the given specification of the induction motor accurately with less time.

Design of induction motor:

The design lies in suitable and economic distribution of iron, copper, insulation and air gap in the machine. Basically the design of electric motor involves the study of the voltages induced in the windings, the load currents and terminal voltages under different loading conditions, the power received or given out by the machine, the speed at which the machine is running under different loading conditions and frequency and the torque produced under different loading conditions. The interrelations of the above quantities decide the suitability of a machine for a particular application. After designing the size and dimensions of the machine parts, the appropriate magnetic and electric circuits must be calculated [8].

Bureau of Indian Standards:

The Bureau of Indian Standards (BIS) has prepared standards for various types of electrical machines to cover the requirements of the consumers. Standardization helps in economy and in the comparison of performance of motors from different manufacturers. The customers can mention the additional specifications apart from the standard specifications to which the equipment must be built and the degree of expected performance accuracy. The standards that summarize the specifications of induction motors are IS 325, IS1231, IS4800 and IS6160 [8].

Mat lab:

It is a high-level language and interactive environment used by engineers and scientists in industry and in education. We can use this tool for collaborating in many disciplines such as control systems, communication systems, signal system, image processing, programming and finance.

It can be used in projects such as to build power grids, control algorithms for high speed vehicles, weather monitoring to visualize the track and intensity of hurricanes, and running simulations to pinpoint optimal dosing for antibiotics. So, it is powerful tool for any type of computation tasks.

Design of induction motor using Mat lab programming:

```
% DESIGN OF THREE PHASE INDUCTION MOTOR -  
MATLAB .
```

```
clc  
clear all  
% input data.  
fprintf('\n  
#####  
##### \n');  
fprintf('\n INPUT THE SPECIATIONS OF THE  
INDUCTION MOTOR\n');
```

```
fprintf('\n
#####
##### \n');
ph=input('\n no of phases=\n');
p=input('power in KW=\n');
v=input('voltage in volts=\n');
f=input('frequency on hz=\n');
po=input('no of poles=\n');
Bav=input('bav in Wb/m2=\n');
q=input('ac in a/m=\n');
Kw=input('winding factor=\n');
pf=input('power facot=\n');
eff=input('eff of m/c=\n');
% to find speed
Ns=(f*120)/po;
ns=(2*f)/po;
% to find output co-efficient
Co=11*Kw*Bav*q*10^-3;
% to find input KVA
Q=p/(eff*pf);
% to find D and L
D=abs((Q/(Co*ns))/1.18)^(1/3);
L=1.18*D;
% to find pole pitch
pp=(pi*D)/po;
iron=input('iron factor=');
% Li- net length
Li=(L-2*0.01)*iron;
pspeed=(pi*D*ns);
fprintf('\n
#####
##### \n');
fprintf('\n DIAMETER AND NET LENGTH OF THE
INDUCTION MOTOR \n');
fprintf('\n
#####
##### \n');
fprintf('\n THE DIAMETER OF THE INDUCTION
MOTOR=% .6f METERS \n',D);
fprintf('\n THE NET LENGTH OF THE INDUCTION
MOTOR=% .6f METERS\n',Li);
% stator design
% flus per pole
flux=Bav*(pi*D*L)/po;
% turns per phase
Tp=v/(4.44*f*flux*Kw);
% no of stator slots
qs=input('\n no of stator slots per pole per phase= \n');
ss=ph*po*qs;
yss=(pi*D)/ss;
sp=ss/ph;
sc=6*Tp;
zss=sc/ss;
cs=ss/po;
fprintf('\n THE COIL SPAN OF THE INDUCTION
MOTOR=% .4f \n',cs);
evenno=input('\n IF THE CS VALUE IS EVEN , THAN
TYPE 2 ELSE ANY OTHER NO= \n');
cs1=2;
if cs1==evenno
    alpha=(1/cs)*180;
```

```
kp=cos((alpha/2)*(pi/180));
kd=(sin((qs*alpha/2)*(pi/180)))/(qs*(sin((qs*alpha/4)*(pi/1
80))));
kws=kp*kd;
end
% conductor size
Is=(p*1e3)/(3*v*eff*pf);
IsL=sqrt(3)*Is;
fprintf('\n THE STATOR LINE CURRENT OF THE
INDUCTION MOTOR=% .4f AMPS \n',IsL);
currentdensity=input('\ncurrent density corresponding to
stator line current= \n');
A=Is/4;
Db=input('\nbare diameter in meters =');
as=pi/(4*Db^2);
density=Is/as;
fprintf('\n THE DENSITY OF STATOR CONDUCTOR OF
THE INDUCTION MOTOR=% .10f A/M2 \n',density);
d1=input('\n diameter of enamelled conductor
CORRESPONDING TO DENSITY in meters = \n');
% slot dimensions
S=zss*as;
sf=input('\n space factor for the slots= \n');
As=S/sf;
wts=flux/(1.7*(ss/po)*Li);
Lmts=(2*L)+(2.3*((pi*D)/4))+ss;
% flux density in stator teeth
Bmst=flux/((ss/p)*wts*Li);
% flux in stator core
fluxstator=flux/2;
B=input('\n flux density of the stator core in wb/m2= \n');
Asc=fluxstator/B;
dcs=Asc/Li;
dcd=input('core depthin meters = \n');
Bcs=(dcs/dcd)*1.2;
h=input('\n height of the core in m= \n');
lip=input('\n lip in meters =\n');
wedge=input('\nwedge in meters = \n');
dss=h+lip+wedge;
Do=D+2*dss+2*dcs;
fprintf('\n
#####
##### \n');
fprintf('\n OUTPUT OF THE STATOR DESIGN OF
INDUCTION MOTOR \n');
fprintf('\n
#####
##### \n');
fprintf('\n THE FLUX PER POLE OF THE INDUCTION
MOTOR=% .4f WB \n',flux);
fprintf('\n THE STATOR TURNS PER POLE OF THE
INDUCTION MOTOR=% .4f TURNS \n',Tp);
fprintf('\n THE STATOR WINDING FACTOR OF THE
INDUCTION MOTOR=% .4f \n ',kws);
fprintf('\n THE STATOR CURRENT OF THE
INDUCTION MOTOR=% .4f AMPS \n',Is);
fprintf('\n THE WIDTH OF THE STATOR TEETH OF
THE INDUCTION MOTOR=% .4f METERS \n',wts);
fprintf('\n THE LENGTH OF MEAN TURN OF THE
INDUCTION MOTOR=% .4f METERS \n',Lmts);
```

```
fprintf('\n THE FLUX DENSITY IN STATOR TEETH OF
THE INDUCTION MOTOR=% .4f WB \n',Bmst);
fprintf('\n THE DEPTH OF STATOR CORE OF THE
INDUCTION MOTOR=% .4f METERS \n',dcs);
fprintf('\n THE OUTER DIAMETER OF STATOR
LAMINATIONS OF THE INDUCTION MOTOR=% .4f
METERS \n',Do);
fprintf('\n
#####
##### \n');
% Rotor design
Lg=0.2+2*sqrt(D*L);
fprintf('\n THE LENGTH OF AIR GAP OF ROTOR OF
THE INDUCTION MOTOR=% .4f METERS \n',Lg);
Lg1=input('\n if lg is greater than 0.3 it must be taken as
0.003 METERS = \n');
Dr=D-2*Lg1;
Sr=input('\n rotor slots= \n');
ysr=(pi*Dr)/Sr;
Ib=(6*Is*Tp*kws*pf)/Sr;
rotordensity=input('\n rotor bar current density in A/m2=
\n');
ab=Ib/rotordensity;
conductorsize=input('\n conductor size standard= \n');
wsr=input('\n width of rotor slot in meters = \n');
dsr=input('\n depth of rotor slot in meters = \n');
slotpitch=(pi*(Dr-2*wsr))/Sr;
wt=slotpitch-wsr;
fluxdensity=flux/((Sr/po)*Li*wt);
Lb=input('\n length of each bar in meters= \n');
Resistivity=input('\n resistivity of the rotor= \n');
rb=Resistivity*Lb/ab;
Tclb=Sr*Ib^2*rb*1e6;
fprintf('\n
#####
##### \n');
fprintf('\n OUTPUT OF THE ROTOR DESIGN OF
INDUCTION MOTOR \n ');
fprintf('\n
#####
##### \n');
fprintf('\n THE AIR GAP LENGTH OF ROTOR OF THE
INDUCTION MOTOR=% .4f METERS \n',Lg);
fprintf('\n THE DIAMETER OF ROTOR OF THE
INDUCTION MOTOR=% .4f METERS \n',Dr);
fprintf('\n THE ROTOR SLOT PITCH OF THE
INDUCTION MOTOR=% .4f METERS \n',ysr);
fprintf('\n THE ROTOR BAR CURRENT OF THE
INDUCTION MOTOR=% .4f AMPS \n',Ib);
fprintf('\n THE WIDTH OF THE ROTOR TEETH AT
THE ROOT OF THE INDUCTION MOTOR=% .4f
METERS \n ',wt);
fprintf('\n THE RESISTANCE OF EACH BAR OF THE
INDUCTION MOTOR=% .12f OHMS \n',rb);
fprintf('\n THE FLUX DENSITY IN ROTOR TEETH OF
THE INDUCTION MOTOR=% .4f WB \n',fluxdensity);
fprintf('\n THE TOTAL COPPER LOSSES IN BARS OF
THE INDUCTION MOTOR=% .4f WATTS \n',Tclb);
fprintf('\n
#####
##### \n');
```

```
% design of end rings .
Ibe=(Sr*Ib)/(pi*po);
currentdensityend=input('\n current density of end ring in
A/m2=\n');
ae=Ibe/currentdensityend;
ae1=ae/1e6;
Doer=(Dr-2*wsr);
de=input('\n depth of ring in meters = \n')
Dier=Doer-2*de;
De=(Doer+Dier)/2;
resistivity=input('\n resistivity of the end ring=\n');
re=(resistivity*pi*De)/ae;
CL=2*Ib^2*re*1e3;
Tcl=Tclb+CL;
% rotor output=input('rotor output in KW =');
slip=(Tcl/(Tcl+(p*1e3)))*100;
% rotor core
dcr=dcs;
Bcr=input('\n flux density in rotor core in wb/m2 \n ');
Di=Dr-2*wsr-2*dcr;
fprintf('\n
#####
##### \n');
fprintf('\n OUTPUT OF THE END RING OF INDUCTION
MOTOR\n ');
fprintf('\n
#####
##### \n');
fprintf('\n THE END RING CURRENT OF THE
INDUCTION MOTOR=% .4f AMPS\n ',Ibe);
fprintf('\n THE AREA OF END RING OF THE
INDUCTION MOTOR=% .4f SQUARE MILL-METERS
\n',ae1);
fprintf('\n THE RESISTANCE OF END RING OF THE
INDUCTION MOTOR=% .12f OHMS \n',re);
fprintf('\n THE TOTAL ROTOR COPPER LOSSES OF
THE INDUCTION MOTOR=% .4f WATTS \n ',Tcl);
fprintf('\n THE SLIP OF THE INDUCTION MOTOR=% .4f
PERCENTAGE \n ',slip);
fprintf('\n THE INNER DIAMETER OF ROTOR
LAMINATION OF THE INDUCTION MOTOR=% .4f
METERS \n',Di);
fprintf('\n
#####
##### \n');
% no load current
% magnetizing current of stator
slotopening=input('\n slot opening = \n');
gaplength=input('\n gap length=\n');
statorratio=slotopening/gaplength;
Kcs=input('\n carters coefficient=\n');
wo=input('wo=');
Kgss=yss/(yss-Kcs*wo);
% rotor
slotopeningrotor=input('\n rotor slot opening= \n');
gaplengthrotor=input('rotor gap opening= \n');
rotorratio=slotopeningrotor/gaplengthrotor;
Kcsr=input('\n rotor carters coefficient= \n');
wo1=input('\nwo1=\n');
Kgsr=ysr/(ysr-Kcsr*wo1);
Kgs=Kgss*Kgsr;
```

```

Kgd=input('\n gap concentration factor \n');
Kg=Kgs*Kgd;
Ag=((pi*D)/4)*L;
Bg=1.36*Bav;
Lge=Kg*gaplength;
Atg=800000*Bg*Kg*Lg1;
% stator teeth
Atp=(ss/po)*wts*Li;
Bts=input('\n flux density of stator teeth=\n');
Btss=1.36*Bts;
fprintf('\n THE flux density of the stator teeth OF THE
INDUCTION MOTOR=% .4f WB/M2 \n',Btss);
ats=input('\n flux density corresponding to Btss in A/m=
\n');
mmfst=ats*dss;
% stator core
Acs=Li*dcs;
Bcs=input('\n flux density of stator core in wb/m2= \n');
Lcs=pi*(D+2*dss+dcs)/(3*po);
atcs=input('\n amper turns of stator in A/m= \n');
Atcs=atcs*Lcs;
% rotor teet
wts=(pi*(Dr-4*dSr)/Sr)-wSr;
Atr=(Sr/po)*wts*Li;
Btr=input('\n flux density at 1/3 ht in wb/m2= \n');
Btra=1.36*Btr;
atr=input('\n flux density in A/m= \n');
Atrt=atr*dSr;
% rotor core
Alr=Li*dcr;
Brl=input('\n flux density in rotor core= \n');
atsr=input('\n flux density in A/M= \n');
lcr=(pi*(Dr-2*dSr-2*dcr))/(3*po);
Atrc=atsr*lcr;
At1=Atg+mmfst+Atcs+Atrt+Atrc;
Im=(0.427*po*At1)/(kws*Tp);
fprintf('\n
#####
##### \n');
fprintf('\n OUTPUT OF NO LOAD CURRENT
(MAGNETIZING CURRENT) OF INDUCTION MOTOR
\n ');
fprintf('\n
#####
##### \n');
fprintf('\n THE MMF REQUIRED FOR AIR GAP OF THE
INDUCTION MOTOR=% .4f AMPS \n ',Atg);
fprintf('\n THE MMF REQUIRED FOR STATOR TEETH
OF THE INDUCTION MOTOR=% .4f AMPS \n',mmfst);
fprintf('\n THE MMF REQUIRED FOR STATOR CORE
OF THE INDUCTION MOTOR=% .4f AMPS \n',Atcs);
fprintf('\n THE MMF REQUIRED FOR ROTOR TEETH
OF THE INDUCTION MOTOR=% .4f AMPS \n',Atrt);
fprintf('\n THE MMF REQUIRED FOR ROTOR CORE OF
THE INDUCTION MOTOR=% .4f AMPS \n',Atrc);
fprintf('\n THE TOTAL MMF OF THE INDUCTION
MOTOR=% .4f AMPS',At1);
fprintf('\n THE TOTAL MAGNETIZING CURRENT PER
PHASE OF THE INDUCTION MOTOR=% .4f AMPS
\n',Im);

```

```

fprintf('\n
#####
##### \n');
% loss component
Vst=input('\n volume of stator teeth in METER
CUBE(M3)= \n');
% iron losses in stator teeth
Wst=Vst*7.6*1e3;
Bst=(pi/2)*Bts;
fprintf('\n THE FLUX DENSITY CORRESPONDING TO
STATOR TEETH OF THE INDUCTION MOTOR=% .4f
WB/M2 \n',Bst);
Lkg=input('\n corresponding to Bst loss per kg in w= \n');
ILst=Lkg*Wst;
% iron loss in stator core
Vsc=input('\n volume of stator core in METER
CUBE(M3)= \n');
wsc=Vst*7.6*1e3;
Bsc=Bcs;
fprintf('\n THE FLUX DENSITY CORRESPONDING TO
STATOR CORE OF THE INDUCTION MOTOR=% .4f
WB/M2 \n',Bsc);
Ilc=input('\n iron loss per kg corresponding to flux density=
\n');
ILsc=Ilc*wsc;
% totoal iron losses
Il=ILst+ILsc;
Itl=2*Il;
% Friction and windage losses
fwlp=input('\n percentage of friction and windage losses=
\n');
fwl=(fwlp/100)*p*1e3;
Tnll=Itl+fwl;
% load current
IL= Tnll/(3*v);
I0=sqrt(IL^2+Im^2);
% power factor
pfo=IL/Im;
phaseangle=acos(pfo)*(180/pi);
% losses and efficiency
rs=((resistivity*Tp*Lmts)/As);
CLs=3*IL^2*rs;
Ip=CL+Itl+fwl+CLs+(p*1e3);
eff1=((p*1e3)/Ip)*100;
% output of the following design
fprintf('\n
#####
##### \n');
fprintf('\n OUTPUT OF LOSS COMPONENT OF
INDUCTION MOTOR \n');
fprintf('\n
#####
##### \n');
fprintf('\n THE IRON LOSS IN STATOR TEETH OF THE
INDUCTION MOTOR=% .4f WATTS \n',ILst);
fprintf('\n THE IRON LOSS IN STATOR CORE OF THE
INDUCTION MOTOR=% .4f WATTS \n',ILsc);
fprintf('\n THE TOTAL IRON LOSSES IN STATOR OF
THE INDUCTION MOTOR=% .4f WATTS \n',Itl);

```

```
fprintf("\n THE TOTAL FRICTION AND WINDIAGE  
LOSSES OF THE INDUCTION MOTOR=%4f  
WATTS\n',fwl);  
fprintf("\n THE TOTAL NO LOAD LOSSES OF THE  
INDUCTION MOTOR=%4f WATTS\n',Tnl);  
fprintf("\n THE TOTAL NO LOAD CURRENT PER  
PHASE OF THE INDUCTION MOTOR=%4f AMPS  
\n',I0);  
fprintf("\n THE POWER FACTOR OF THE INDUCTION  
MOTOR=%4f \n',pfo);  
fprintf("\n THE PHASE ANGLE OF NO LOAD CURRENT  
OF THE INDUCTION MOTOR=%4f  
DEGREES\n',phaseangle);  
fprintf("\n THE EFFICIENCY AT FULL LOAD OF THE  
INDUCTION MOTOR=%4f DEGREES\n',eff1);  
fprintf("\n  
#####  
##### \n');
```

CONCLUSION:

The demand of motor design program for educational purposes was the motivation behind this study. The scope of the project is featuring mat lab programming for the design of squirrel cage induction motor in its basic form useful to designing and in teaching field. The developed mat lab programming provides good support for the students who are learning the design process as a part of their curriculum. The design procedure and with the different parameter modifications they arrive at the optimized solution. This helps them to analyze the effects of different parameter variations easily and learn the design of induction motor effectively. The present work has concentrated on the design of standard squirrel cage induction motor which can be extended for designing energy efficient machines as a future scope.

APPENDIX:

1. Air gap flux density (B_{av})-0.3 to 0.6wb/m².
2. Ampere conductor (ac/q)-5000 to 45000ac/m.
3. Efficiency for 4 pole squirrel cage induction motor - 72% to 91%.
4. Efficiency for 8 pole squirrel cage induction motor -75% to 90%.
5. Power factor for 4 pole -0.75 to 0.92.
6. Power factor for 4 pole -0.66 to 0.89.
7. Peripheral speed -60m/s to 75m/s.
8. Ventilating ducts- 8 to 10mm.
9. Insulation materials –classes E, B &F.
10. Current density in stator conductor-3.5 to 6a/mm²
11. Slot pitch for open type of slots-15 to 25mm.
12. Mean flux density in tooth lines-1.3 to 1.7 wb/m².
13. Maximum flux density in stator teeth-1.7 wb/m².
14. Flux density in stator core -1.2 to 1.4 wb/m².
15. Current density in rotor bars-4 to 7 A/mm².
16. Current density in end rings -5A/mm².
17. Flux density in rotor core \approx stator core (Higher than stator value).

18. Friction and windage losses -1.0 to 5.5 %.
19. Resistivity of copper -0.021 ohm/m at 75⁰C.
20. Iron factor-0.9.
21. Space factor for the slots-0.4.
22. W_0 for air gap in stator-2.
23. W_{01} for air gap in rotor-1.5.

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