

Design of Three Phase Induction Motor



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Introduction

An induction motor is the most modest electrical machine from constructional point of view, in the majority of the cases. Induction motor works on the principle of induction where electro-magnetic field is induced into the rotor when rotating magnetic field of stator cuts the stationary rotor. Induction machines are by far the most common type of motor used in industrial, commercial or residential settings. Through this project we aim at designing a three phase squirrel cage induction motor .

The essential parts of an induction motor are stator and a rotor. The construction of stator for any induction motor is almost the same. But the rotor construction differs with respect to the type used. The stator is the outer most component in the motor which can be seen. It may be constructed for single phase, three phase or even poly phase motors. But basically only the windings on the stator vary, not the basic layout of the stator. It is almost same for any given synchronous motor or a generator. It is made up of number of stampings, which are slotted to receive the windings. The three phase windings are placed on the slots of laminated core and these windings are electrically spaced 120 degrees apart. These windings are connected as either star or delta depending upon the requirement. The leads are taken out usually three in number, brought out to the terminal box mounted on the motor frame. The insulation between the windings are generally varnish or oxide coated.

The rotor consists of a cylindrical laminated core with parallel slots for carrying the rotor conductors, which are not wires, as we think, but thick, heavy bars of copper or aluminium (aluminium) or its alloys. The conductor bars are inserted from one end of the rotor and as one bar in each slot. There are end rings which are welded or electrically braced or even bolted at both ends of the rotor, thus maintaining electrical continuity. These end rings are short-circuited, after which they give a beautiful look similar to a squirrel thus the name. One important point to be noted is that the end rings and the rotor conducting bars are permanently short-circuited, thus it is not possible to add any external resistance in series with the rotor circuit for starting purpose. The rotor conducting bars are usually not parallel to the shaft, but are purposely given slight skew.

We aim to design this machine by taking into consideration the design features like main dimensions, stator design , rotor design and the performance features like no load current , loss component ,leakage reactance and loss and efficiency . For this purpose , we will be using MATLAB for coding & C language can also be used incorporated depending on the ease of usage and productivity.

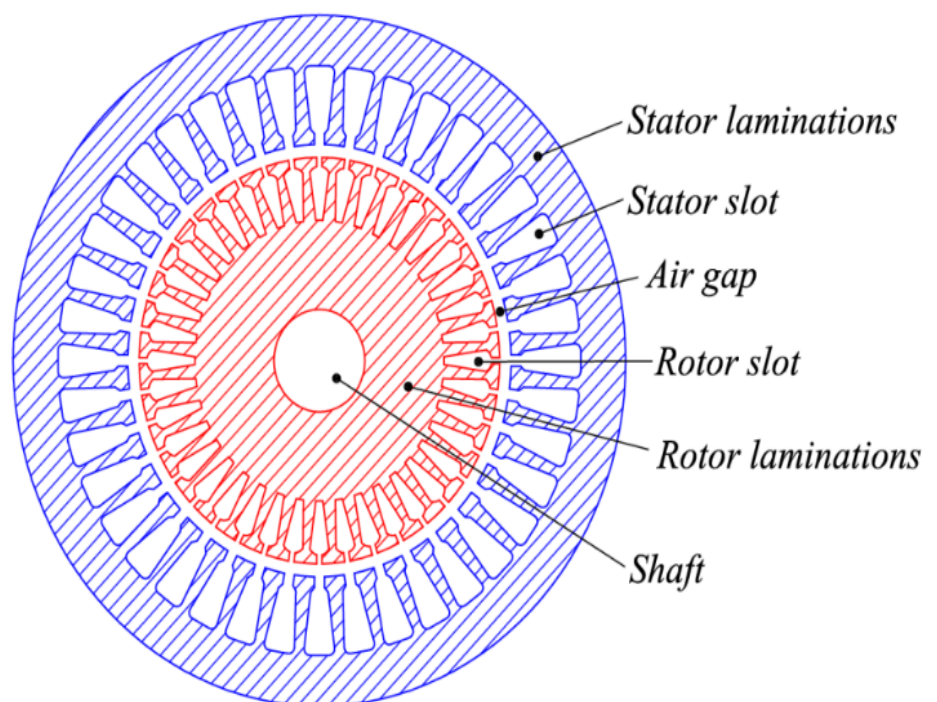
Design procedure of Induction Motor

The main specifications for the design of a three phase squirrel cage induction motor are: rated output power in HP or kW, frequency in Hz, voltage in volts, speed in rpm, efficiency, power factor and full load current in ampere.

The standard specification for the design of an induction motor are materials (lamination thickness, conductor diameter), performance indexes (efficiency, power factor, starting torque, starting current, breakdown torque), temperature by insulation class, frame sizes, shaft height, cooling types, service classes, protection classes, etc. are specified in national (or international) standards (NEMA, IEEE, IEC, EU, etc.) to facilitate the induction motor for various applications

The main purpose of designing an induction motor is to obtain the complete physical dimensions of all the parts of the machine as mentioned below to satisfy the given specifications and stator and rotor laminations of an induction motor are shown in the figure below

- The main dimensions of the stator
- Details of stator windings
- Design details of rotor and its windings



The stator and rotor dimensions are determined by independent variables which are: stator slot height, stator tooth width, rotor slot height, rotor tooth width, air-gap length, air gap flux density, stack length, outer stator diameter, stator wire size and electrical steel type. Besides the above independent variables, the design involves some non-linear constraints which concern mainly the motor performances. They are stator winding temperature, rotor bar temperature, flux density in the stator. The type of winding adopted in this design is the squirrel cage type as it is simpler and economical, which consists of a number of bars embedded in the rotor slots and connected at both ends by means of end rings.

The major steps in designing an IM may be divided into 5 areas: electrical, dielectric, magnetic, thermal and mechanical.

Electrical design: To supply the IM, the supply voltage, frequency, and number of phases are specified. From this data and the minimum power factor and a target efficiency, the phase connection (star or delta), winding type, number of poles, slot numbers and winding factors are calculated. Current densities are imposed.

Magnetic design: Based on output coefficients, power, speed, number of poles, type of cooling, and the rotor diameter is calculated. Then, based on a specific current loading (in A/m) and air gap flux density, the stack length is determined. Fixing the flux densities in various parts of the magnetic circuit with given current densities and slot mmfs, the slot sizing, core height, and external stator diameter D_o are all calculated. Choosing D_o , which is standardized, the stack length is modified until the initial current density in the slot is secured. It is evident that sizing the stator and rotor core may be done many ways based on various criteria.

Insulation design: Insulation material and its thickness, be it slot/core insulation, conductor insulation, end connection insulation, or terminal leads insulation depends on machine voltage insulation class and the environment in which the motor operates. There are low voltage 400V/50Hz, 230V/60Hz, 460V/60Hz 690V/60Hz or less or high voltage machines (2.3kV/60Hz, 4kV/50Hz, 6kV/50Hz). When PWM converter fed IMs are used, care must be exercised in reducing the voltage stress on the first 20% of phase coils or to enforce their insulation or to use random wound coils.

Thermal design: Extracting the heat caused by losses from the IM is imperative to keep the windings, core, and frame temperatures within safe limits. Depending on application or power level, various types of cooling are used. Air cooling is predominant but stator water cooling in the stator of high speed induction motors (above 10,000 rpm) is frequently used. Calculating the loss and temperature distribution and the cooling system represents the thermal design.

Mechanical design: Mechanical design refers to critical rotating speed, noise, and vibration modes, mechanical stress in the shaft, and its deformation displacement, bearings design, inertia calculation, and forces on the winding end coils during most severe current transients.

Output Equation

Output equation is the mathematical expression which relates the output of the machine with its main dimensions. Rating of a three phase induction motor, Q in kVA is given by:

$$Q = 3E_{ph}I_{ph}10^{-3}$$

$$Q = 3 \times 4.44 K_w f \phi T_{ph} I_{ph} 10^{-3}$$

where

$$f = \frac{pn_s}{2}$$

Since the rating is given in kW, converted to kVA by the relation:

$$kVA = \frac{kW}{\eta \cos \phi}$$

Specific magnetic loading, B_{av} is obtained by dividing total flux around the air gap by area of flux path in the air gap as:

$$B_{av} = \frac{p\phi}{\pi DL}$$

Specific electric loading, a_c is obtained by dividing total armature ampere conductors by armature periphery at the air gap.

$$a_c = \frac{I_z Z}{\pi D} = \frac{6T_{ph} I_{ph}}{\pi D}$$

Rearranging the equations

$$\phi = \frac{B_{av} \pi D L}{p}$$

$$T_{ph} I_{ph} = \frac{ac \pi D}{6}$$

Substituting gives output equation of an AC machine,

$$Q = C_0 D^2 L n_s$$

where output coefficient, $C_0 = 1.11 \pi^2 B_{av} ac K_w 10^{-3}$

$$= 1.1 B_{av} ac K_w 10^{-3}$$

Choice of Specific Magnetic loading or Air gap flux density

B_{av} is selected normally from standard design tables and the value is limited by losses in the teeth and magnetizing current. Higher value of B_{av} means the winding requires less number of turns per phase, but higher value of overload capacity. For 50 Hz machine, the value of B_{av} is between 0.35 and 0.60 Wb/m

Choice of Specific electric loading

Specific electric loading or ampere conductors per meter of air gap circumference, ac is selected from traditional design tables. High value of ac means less electric material, but higher electric losses and lower overload capacity. Normal range of ac is between 10000 ac/m and 450000 ac/m.

Calculation of the main dimensions

The armature diameter and stator core length are known as the main dimensions.

Aspect ratio: The output equation, gives the relation between $D^2 L$ product and output of the machine,

$$D^2 L = \frac{Q}{C_0 n_s}$$

The operating characteristics of an induction motor are mainly influenced by the ratio L/τ . The ratio, D/L determines the shape of a pole, square or rectangular.

$$\lambda = \frac{L}{\tau} = \frac{L}{\left(\frac{\pi D}{p}\right)}$$

Following are the various design considerations based on which a suitable value for λ can also be assumed from table

Table 7.1 Value of λ

Sl No.	Design consideration	Value of λ
1	Minimum overall cost	1.5 to 2.0
2	Good efficiency	1.4 to 1.6
3	Good overall design	1.0 to 1.1
4	Good power factor	1.0 to 1.3

For obtaining the best power factor, the following relation is usually assumed for calculating D and L

$$\tau = \sqrt{0.18L}$$

Check for peripheral velocity

For normal construction of induction motors, the calculated diameter of the motor should be such that the peripheral velocity must be below 30 m/sec.

$$v = \pi Dn$$

C Code and Output

```
#include <stdio.h>
#include <conio.h>
```

```

#include <math.h>

#define pi 3.141592654

float ns,nd,p_f,P,n,p,Q,m,Es,f,Bav,ac,Co,Kw,H,a,b,c,D,L,t,Wd,Ki,Li,Ns;

float F,Kws,qs,ss,yss,Ts,Tc,Ts1,T,Zss,Cs,Kp,Kd,Kws1;

float Is,Id,As,As1,d,d1,wire,cov;

float
Os,Or,Wt,Fd,wsd,sd,sld,Wss,Lip,swe,dss,slackd,slackw,dss1,sw,sw,Wss1,slw,AA,Lmts;

float Fs,Fds,Acs,Dcs,Do;

float Ibr,Idr,Abr,Dbr,Wbr,Wbr1,Dbr1,AAbr,Wbrt,Fbrd,Lbr,Rbr,PLC;

float Ier,Ierd,Aer,Ted,Ded;

float Deo,Dei,Dem,Red,PLC1,PLC2,slip;

float Drc,Drcia;

float ratio1,ratio2,ratio3,Kcs,Kgss,Kcr,Kgsr,Kgs,Kcd,Kgd,Kg,lge,Agp,Bg,ATs;

float Wts,Ats,Bts,ATs1,ats;

float Acs1,Bcs,Lcs,ATs2,ats1;

float Wrt,Art, Brt,ATs3,ats2;

float Acr,Bcr,atr,Lcr,ATs4,TATs,Im;

float West,Bstmax,Irlst,Isrlst;;

float Isrlsc,Pmsc,Wesc,Irlsc,TIrls,FWI,FWI1,Tn11,I1,In1,p_fnl,ap_fnl,ap_fnl1,AIrls;

float mo=(4*pi), Gss;

float xs,sldr=0.5,slackdr=0,swer=1.5,Lipr=0.5,Grr,Gsr,TG;

float Lov,xo;

float Xm,as,ar,Xz,TX;

float Zlss,Isc,p_fsc,asc,asc1;

float R,PSCL,Rrs,Rt;

float OPfl,IPfl,eff;

float lg,Dr;

float Dcs1,Sr,ysr;

int key;

FILE *fp;

/* main dimension*/

void md()
{
    key=1;

    fp=fopen("MDFile.txt","w");

    printf("\n\n\n\t\t\tMAIN DIMENSIONS");

    printf("\n\nEnter the power(p) in kW:");

```

```

scanf("%f",&P);
m=3; /*no of phase*/
f=50; /*frequency*/
printf("\nEnter the full load efficiency(n):");
scanf("%f",&n);
printf("\nEnter the power factor(p_f):");
scanf("%f",&p_f);
if((P>=0.75 && P<=100)&&((n>=0.72 && n<0.81)|| (p_f>=0.75 && p_f<0.82)))
{
    p=4;
}
else if((P>=0.75 && P<=100) &&((n>=0.81 && n<0.83)|| (p_f>=0.82 && p_f<0.84)))
{
    p=4;
}
else if((P>=0.75 && P<=100) &&((n>=0.83 && n<0.86)|| (p_f>=0.84 && p_f<0.87)))
{
    p=4;
}
else if((P>=0.75 && P<=100) &&((n>=0.86 && n<0.88)|| (p_f>=0.87 && p_f<0.89)))
{
    p=4;
}
else if((P>=0.75 && P<=100) &&((n>=0.88 && n<0.90)|| (p_f>=0.89 && p_f<0.90)))
{
    p=4;
}
else if((P>=0.75 && P<=100) &&((n>=0.90 && n<0.91)|| (p_f>=0.90 && p_f<0.92)))
{
    p=4;
}
else if((P>=0.75 && P<=100) &&((n>=0.91 && n<0.95)|| (p_f>=0.92 && p_f<=1)))
{
    p=4;
}

```

```

else if((P>=2.20 && P<=100) && ((n>=0.75 && n<0.81) || (p_f>=0.66 && p_f<0.69)))
{
    p=8;
}
else if((P>=2.20 && P<=100) && ((n>=0.81 && n<0.82) || (p_f>=0.69 && p_f<0.78)))
{p=8;
}
else if((P>=2.20 && P<=100) && ((n>=0.82 && n<0.85) || (p_f>=0.78 && p_f<0.83)))
{
    p=8;
}
else if((P>=2.20 && P<=100) && ((n>=0.85 && n<0.89) || (p_f>=0.83 && p_f<0.85)))
{
    p=8;
}
else if((P>=2.20 && P<=100) && ((n>=0.90 && n<0.91) || (p_f>=0.85 && p_f<0.89)))
{
    p=8;
}
else if((P>=2.20 && P<=100) && ((n>=0.91 && n<0.95) || (p_f>=0.89 && p_f<=0.92)))
{
    p=8;
}
Ns= 120*f/(p);
ns=Ns/60;

    if(P>=0.75 && P<3.75)
    {
        Bav=0.38;
        ac=15000;
    }
    else if(P>=3.75 && P<10)
    {
        Bav =0.42;
    }

```

```
        ac= 21000;

    }
    else if (P>=10 && P<15)
    {
        Bav=0.44;
        ac= 22000;
    }
    else if(P>=15 && P<30)
    {
        Bav=0.45;
        ac= 23000;
    }
    else if(P>=30 && P<40)
    {
        Bav =0.5;
        ac=25000;
    }
    else if (P>=40 && P<50)
    {
        Bav=0.5;
        ac=27000;
    }
    else if(P>=50 && P<75)
    {
        Bav=0.53;
        ac=32000;
    }
    else if(P>=75 && P<100)
    {
        Bav=0.55;
        ac =35000;
    }
    else if(P==100)
    {
        Bav=0.58;
```

```

        ac=40000;
    }

    Kw=0.955;

    fprintf(fp,"\nDesign a %0.2f kW, %0.0f phase,%0.0f volt,%0.0f Hz,%0.0f r.p.m
squirrel cage induction motor ", P,m,Es,f,(ns*60));

    fprintf(fp,"\nhaving a full load efficiency of %0.03f and a power factor of
%0.3f . The temperature ",n,p_f);

    fprintf(fp,"\nrise is not to be exceeding T Celsius\n");

    fprintf(fp,"\n\n\n\n\n                                MAIN DIMENSION");

    fprintf(fp,"\n The input power is %0.2f kW",P);

    fprintf(fp,"\n The number of phase is %0.0f.",m);

    fprintf(fp,"\n The Line frequency is %0.0f Hz.",f);

    fprintf(fp,"\nThe full load efficiency is %0.3f.",n);

    fprintf(fp,"\nThe synchronous speed is %0.0f r.p.m.", (ns*60));

    fprintf(fp,"\nThe value of specific magnetic loading is %0.3f Wb/m^2.",Bav);

    fprintf(fp,"\nThe value of specific electric loading is %0.3f A/m^2.",ac);

    fprintf(fp,"\nThe value of winding factor is %0.3f.", Kw);

    fprintf(fp,"\nThe no. of pole is %0.0f.",p);

    Q= P/(n*p_f);

    fprintf(fp,"\nkVA %0.3f is kVA.",Q);

    Co=11*Bav*ac*Kw/1000;

    fprintf(fp,"\nOutput coefficient is %0.3f .",Co);

    H=Q/(Co*ns);

    fprintf(fp,"\nProduct D*D*L is %0.3f m^3 ", H);

    samel:

    fprintf(fp,"\nFor good power factor ,L/t should be between 1 to 1.5.");

    printf("\nFor good power factor ,L/t should be between 1 to 1.5.\n");

    c=1.2; /*value of L/t*/

    a=c*pi/p;

    b=H/a;

    D=pow(b, .333);

    fprintf(fp,"\nDiameter of the core is %0.3f m." ,D);

    L=a*D;

    fprintf(fp,"\nDiameter of the core is %0.3f m.", L);

    t=L/c;

    fprintf(fp,"\nThe value of pole pitch is %0.3f m.",t);

    int i;

```

```

for(i=1;i<2;i++)
{
    printf("\nDiameter of the core D=%0.3f m.\n",D);
    printf("\nLength of the core L=%0.3f m.\n",L);
    printf("\nThe value of Pole Pitch t=%0.3f m.\n",t);
    printf("\nWant to modify these values ?\n");
    printf("\n1-for 'yes' and 0-for 'no':");
    int y;
    scanf("%d",&y);
    if(y==1)
        goto same1;
    else if(y==0)
        break;
    else
    {
        printf("\nEnter the proper value.\n");
        continue;
    }
}

printf("\nEnter the modified diameter in m:");
scanf("%f",&D);
printf("\nEnter the modified core length in m:");
scanf("%f",&L);
t=(pi*D)/p;
c=L/t;
printf("\nThe modified pole pitch in m is :%0.3f\n",t);
fprintf(fp,"\nModified diameter of the core is %0.3f m ",D);
fprintf(fp,"\nModified length of core is %0.3f m" ,L);
fprintf(fp,"\nModified value of pole pitch is %0.3f m.",t);
fprintf(fp,"\nModified value of L/t is %0.3f.",c);

fprintf(fp,"\nIf the length of core (L) is greater than 130 mm then radial
ventilation duct is necessary.");

Ki=0.9 ;/*stacking factor*/
fprintf(fp,"\nThe value of stacking factor is %0.3f.",Ki);
if(L*1000>=120)
{
    printf("\nLength of core is greater or equal to 120\n");
}

```

```

        printf("\nRadial ventilation duct is necessary.\n");
        fprintf(fp, "\nLength of core is greater or equal to 120.");
        fprintf(fp, "\nRadial ventilation duct is necessary.");
        Wd=0.01; /*Width of radial duct*/
        fprintf(fp, "\nWidth of radial ventilation duct is %0.3f m.", Wd);
        nd=(L*1000)/120;
        if(nd-((int)(nd)) > 0.5)
            {nd=((int)(nd)) + 1;}
        else
            {nd=((int)(nd));}
        fprintf(fp, "\nThe number of radial duct is %0.0f.", nd);
        Li=Ki*(L-nd*Wd);
        fprintf(fp, "\nNet Iron Length is %0.3f m .", Li);}
    }
else
{
    fprintf(fp, "\nNo radial ventilation duct is necessary.");
    Li=Ki*L;
    fprintf(fp, "\nNet iron length is %0.3f m", Li);
}

    fprintf(fp, "\nLaminations of Lohys steel 0.5 mm thick are used.\n");
fclose(fp);
}

int sdm()
{
    /*stator design*/

    key=2;
    FILE*fp;
    fp=fopen("SDFile.txt", "w");
    fprintf(fp, "\n\n\n\n          STATOR DESIGN");
    printf("\t\t\t\t\tSTATOR DESIGN");

                                /*winding*/

    printf("\n\nWINDING");
    fprintf(fp, "\n\n\nWINDING");
    int conn;
    printf("\nEnter the input voltage(V):");

```

```

scanf("%f",&Es);

connc:

printf("\nSelect the connection type.\n1-Star.\n2-Delta.\n:");

scanf("%d",&conn);

if(conn==1)

    Es=Es/sqrt(3);

else if(conn==2)

    Es=Es;

else

{

    printf("\nPress the proper number.");

    goto connc;

}

fprintf(fp,"\nStator voltage per phase is %0.3f Volt",Es);

Kws=0.955;/*stator winding factor*/

F=Bav*t*L;

fprintf(fp,"\nFlux per pole is %f Wb",F);

Ts=((int) (Es/(4.44*f*F*Kws)));

fprintf(fp,"\nStator turn per phase is %0.0f",Ts);

qs= 2 ;/*slot per pole per phase*/

fprintf(fp,"\n Taking the value of slot per pole per phase for stator is %0.0f",qs);

Ss=((int) (m*p*qs));

fprintf(fp,"\nNumber of Stator slots is %0.0f",Ss);

yss=pi*D/Ss;

fprintf(fp,"\nStator slot pitch is %0.03f m.",yss);

T=((int) (6*(Ts)));

fprintf(fp,"\nTotal stator conductor is %0.0f.",T);

Zss=((int) (T/Ss));

fprintf(fp,"\nConductor per slot is %0.0f.",Zss);

cps:

printf("\nThe conductor per slot is %0.0f.\n",Zss);

fprintf(fp,"\nModified conductor per slot is %0.0f.",Zss);

Tc=((int) (Zss*Ss));

fprintf(fp,"\ntotal conductors used is %0.0f.",Tc);

Ts1=((int) (Tc/6));

fprintf(fp,"\nStator turn per phase is %0.0f.",Ts1);

```

```

if ((Ts-Ts1)>5)
{
    printf("\nThe stator turn per phase is %0.0f.\n",Ts);
    printf("\nCalculated value of stator per phase is %0.0f.\n",Ts1);
    printf("\nIt is necessary to change the value of magnetic loading (BaV) \n
or Conductor per slot(ZSS).\n");
    fprintf(fp,"\nThe stator turn per phase is %0.0f.\n",Ts);
    fprintf(fp,"\nCalculated value of stator per turn is %0.0f.\n",Ts1);
    fprintf(fp,"\nt is necessary to change the value of magnetic loading (BaV)
\n or Conductor per slot(ZSS).\n");
    changel:
    printf("\n--Change BaV.\n2--ZSS.\n:");
    int ch;
    scanf("%d",&ch);
    if (ch==1)
    {
        float A,B;
        A=(Ts/Ts1)*Bav;
        B=A*t*L;
        printf("\nModified value of BaV is %0.3f Wb/m^2.",A);
        printf("\nModified value of flux per pole is %f Wb.",B);
        fprintf(fp,"\nModified value of BaV is %0.3f Wb/m^2.",A);
        fprintf(fp,"\nModified value of flux per pole is %f Wb.",B);
        printf("\nPress any key...");
        getch();
        md();
        sdm();
        return 0;
    }
    else if(ch==2)
        goto cps;
    else
    {
        printf("\nPress the proper number");
        goto changel;
    }
}

```

```

else
{
    printf("\nThe value of stator per phase is %0.0f and the calculated turn per
phase is %0.0f ie very near\n.",Ts,Tsl);

    printf("\nSo no modification of value of BaV.\n");

    fprintf(fp,"\nThe value of stator per phase is %0.0f and the calculated turn
per phase is %0.0f ie very near\n.",Ts,Tsl);

    fprintf(fp,"\nSo no modification of value of BaV.\n");

    fprintf(fp,"\nChorded winding of pitch 8/9 is used.");

}

Cs=((int) (Ss/p));

fprintf(fp,"\nCoil span or slot per hole is %0.0f.",Cs);

Kp=cos(pi/(2*Cs));

fprintf(fp,"\nPitch factor is %0.3f.",Kp);

Kd=sin(qs*(pi/(2*Cs)))/(qs*sin(pi/(2*Cs)));

fprintf(fp,"\nDistribution factor is %0.3f.",Kd);

Kws1=Kp*Kd;

fprintf(fp,"\nStator winding factor is %0.3f.",Kws1);


                                /*Conductor Size*/

printf("\t\t\t\t\tCONDUCTOR SIZE");

fprintf(fp,"\n\n\n\n\t\t\t\t\tCONDUCTOR SIZE");

Is=(P*1000)/(m*Es*n*p_f);

fprintf(fp,"\nStator current per phase is %0.3f",Is);

Id=4;/*Current density*/

fprintf(fp,"\nTaking a current density in stator conductor is %0.3f A/mm^2.",Id);

As=Is/Id;

printf("\nArea of the stator conductor is %0.3f mm^2.\n",As);

if (P<50)

{

    printf("\nThe power is %0.2f kw. So conductor type is round.\n",P);

    fprintf(fp,"\nThe power is %0.2f kw. So conductor type is round.",P);

    fprintf(fp,"\nArea of the stator conductor is %0.3f mm^2.\n",As);

    d=sqrt((4*As)/pi);

    fprintf(fp,"\nDiameter of the stator conductor is %0.3f mm.",d);

    printf("\nDiameter of the stator conductor is %0.3f mm.\n",d);

    wire=1;/*number of wires */

```

```

        fprintf(fp, "\nthe number of wires in the conductor is %0.0f", wire);
        d=1.25 ; /*diameter of conductor*/
        fprintf(fp, "\nUsing %0.0f conductor of diameter %0.3f mm.", wire, d);
        d1=1.325; /*diameter of insulation with conductor*/
        fprintf(fp, "\nCorresponding diameter of the insulated conductor is %0.3f
mm.", d1);

        As1=wire*(pi*d1*d1)/4;

        fprintf(fp, "\nArea of the conductor provided with insulation is %f
mm^2.", As1);
    }
    if (P>=50)
    {
        wire=1;

        printf("\nThe power is %0.2f Kw. So the conductor type is rectangle.\n", P);

        fprintf(fp, "\nThe power is %0.2f Kw. So the conductor type is
rectangle.", P);

        printf("\nArea of the conductor is %0.3f mm^2", As);

        printf("\nEnter the dimension of the conductor (width*depth) in mm:");

        scanf("%f%f", &d1, &d);

        fprintf(fp, "\nThe dimensions of the rectangular conductor is %0.3f *
%0.3f (in mm)", d, d1);

        printf("\nEnter the thickness of the covering (in mm):");

        scanf("%f", &cov);

        fprintf(fp, "\nDimensions of the Insulated rectangular conductor is %0.3f *
%0.3f (in mm)", (d+(2*cov)), (d1+(2*cov)));

        As1=wire*(d1+cov)*(d+cov);

        fprintf(fp, "\nModified insulated area is %0.3f mm^2", As1);

        As=As1;
    }

    printf("\t\t\t\t\tSLOT DIMENSION");

    fprintf(fp, "\n\n\n\n\n\t\t\t\t\tSLOT DIMENSION");

    if (P<50)
    {
        printf("\nNow, each conductor consists of %0.0f wire outside diameter %0.3f
mm\nn.", wire, d1);

        fprintf(fp, "\nNow, each conductor consists of %0.0f wire outside diameter
%0.3f mm\nn.", wire, (d1+(cov*2)));
    }

```

```

if (P>=50)

{
    printf("\nNow, each conductor consists of %0.0f strip of outside dimension
of %0.3fmm*%0.3f mm\n",wire, (d1+(cov*2)), (d+(2*cov)));

    fprintf(fp, "\nNow, each conductor consists of %0.0f strip of outside
diameter %0.3f mm.", wire, (d1+(cov*2)));
}

printf("\nNumber of conductor per slot is %0.0f and %0.0f of wires/strips in
slot.\n", Zss, (Zss*wire));

int j;

    for (j=1; j<2; j++)

    {

        wsd=15; /*wires along slot depth*/

        if(P<50)

            sd=wsd*d1;

        if(P>=50)

            sd=wsd*(d1+(cov*2));

        Os=1.5; /*Slot insulation in depth*/

        sld=Os;

        swe=3;

        Lip=1;

        dss=sd+sld+swe+Lip;

        printf("\nSlot depth without slack is %0.3f mm\n", dss);

        slackd=0.625;

        dss1=dss+slackd;

        wsw =5;

        if (P<50)

            sw=wsw*d1;

        if (P>=50)

            sw=wsw*(d+(cov*2));

        Or=1;

        slw=Or;

        Wss=sw+slw;

        printf("\nSlot width without slack is %0.3f mm\n", Wss);

        slackw=0.375;

        Wss1=Wss+slackw;

        fprintf(fp, "\nSlot depth                Slot width");

        fprintf(fp, "\n%0.0f wire %0.0f*%0.3f=%0.3fmm %0.0f wire
%0.0f*%0.3f=%0.3f mm", wsd, wsd, d1, sd, wsw, wsw, d1, sw);

```

```

        fprintf(fp, "\nSlot lining %0.0f*0.5=%0.3fm Slot lining
%0.0f*0.5=%0.3fmm", Os, sld, Or, slw);

        fprintf(fp, "\nWedge=%0.3fmm slack = %0.3f mm", swe, slackw);

        fprintf(fp, "\nLip      =%0.3f mm", Lip);

        fprintf(fp, "\nSlack    =%0.3f mm", slackd);

        fprintf(fp, "\n_____");

        fprintf(fp, "\nSlot depth dss      =%0.3f mm slot width Wss
=%0.3f mm", dss1, Wss1);

        fprintf(fp, "\nBefore proceeding further the flux density at
section having minimum width of teeth must be checked.");

        AA=(pi*D*1000/Ss);

        fprintf(fp, "\nSlot pitch at AA %0.3f mm.", AA);

        Wt=AA-Wss1;

        fprintf(fp, "\nFlux density in teeth %f", Fd);

        Fd=((F*p)/(Ss*Wt*Li))*1000;

        fprintf(fp, "\nFlux density in teeth %f", Fd);

        printf("\nFlux density in teeth (max value is 1.7Wb/mm^2) is
%0.3f Wb/mm^2\n", Fd);

        printf("\nWant to modify the flux density?\n");

        printf("\n1-'yesy' and 0-'no'");

        int g;

        scanf("%d", &g);

        if (g==1)

            continue;

        else

            break;

    }

    fprintf(fp, "\nThe flux density within limits.");

    fprintf(fp, "\nThe dimension of stator slots are");

    if (j==1)

        fprintf(fp, "\nWidth = %0.3f mm \n Modified depth = %0.3f
mm, Wss1, dss1");

    else

        fprintf(fp, "\nModified width = %0.3f mm \nModified depth =
%0.3fmm, Wss1, dss1");

    Lmts =(2*L)+(2.3*t)+0.24;

    fprintf(fp, "\nLength of maximum turn %0.3fmm", Lmts);

```

/* STATOR CORE */

```

printf("\t\t\t\tSTATOR CORE");

fprintf(fp, "\n\n\n\n          STATOR CORE");

Fs=F/2;

printf("\nFlux in stator core %f Wb",Fs);

Fds=1.2;

printf("\nAssuming a flux density of %0.2f Wb/mm^2",Fds);

Acs=Fs/Fds;

printf("\nArea of the stator core %f m^2",Acs);

Dcs=Acs/Li;

printf("\nDepth of stator core %f mm",Dcs);

Dcs1=Dcs*1000;

printf("\n\nThe depth of core used is %f mm",Dcs1);

Do=D*1000+2*dss1*Dcs1;

printf("\nOuter diameter of stator laminations %0.3f mm",Do);

fclose(fp);

return 0;

}

void rdt()

{

    key=3;

    FILE*fp;

    fp=fopen("RD.txt","w");

    printf("\t\t\t\tROTOR DESIGN");

    fprintf(fp, "\n\n\n\n          ROTOR DESIGN");

    printf("\t\t\t\n\nAIR GAP");

    fprintf(fp, "\n\n\n\n          AIR GAP");

    lg=0.2+( 2*(sqrt(D*L)));

    fprintf(fp, "\nLength of the air gap %0.3f mm",lg);

    Dr=(D*1000)-(2*lg);

    fprintf(fp, "\nDiameter of the rotor core %0.3f mm",Dr);

    printf("\t\t\t\tROTOR SLOTS");

    fprintf(fp, "\n\n\n\n          ROTOR SLOTS");

    fprintf(fp, "\n\nThe number of rotor slots chosen s.t. smooth starting and
    accelerating conditions are obtained. This is secured by adopting one slot less or
    one slot more per pole pairs, in the rotor than slots");

```

```

fprintf(fp, "\nTaking the rotor slot pair of pole more than the stator slots.");
Sr=Ss+p/2;
fprintf(fp, "\nNumber of rotor slots %0.0f", Sr);
ysr=(pi*Dr)/Sr;
fprintf(fp, "\nRotor pole pitch %0.3f mm", ysr);

fprintf(fp, "\n\n\n\n      ROTOR BARS");
Ibr=(2*m*Kws*(int) (Tsl)*Is*p_f)/Sr;
fprintf(fp, "\nCurrent in each rotor bar %f", Ibr);
Idr=6;
fprintf(fp, "\nTaking a current density for rotor bars %0.3f A/mm^2: ", Idr);
Abr=Ibr/Idr;
fprintf(fp, "\nArea of each rotor bar %0.3f mm^2", Abr);
printf("\nArea of rotor bar %0.3f mm^2.\n", Abr);
Dbr=11;
fprintf(fp, "The depth of the rotor bar is %0.3f mm: ", Dbr);
Wbr=Abr/Dbr;
fprintf(fp, "The width of the rotor bar is %0.3f mm", Wbr);
fprintf(fp, "\nA rotor bar %0.3f mm wide and %0.3f mm deep is used.\n", Wbr, Dbr);
Wbr1=Wbr+1;
Dbr=Dbr+3;

fprintf(fp, "\nThe dimension of rotor slots is :\n Width= %0.3f mm and Depth= %0.3f mm ", Wbr1, Dbr1);

fprintf(fp, "\nBefore proceeding further the flux density at root of teeth must be checked.");

AAbr=pi*((D*1000)-(2*13))/Sr;
fprintf(fp, "Slot pitch at the root of teeth %0.3f mm.", AAbr);
Wbrt=AAbr-Wbr1;
fprintf(fp, "\nSlot width at the root of teeth %0.3f mm.", Wbrt);
Fbrd=(F*p*1000)/(Sr*Li*Wbrt);
fprintf(fp, "\nFlux density at the root of the rotor teeth is %0.3f Wb/^2", Fbrd);
fprintf(fp, "\nThis is within limit and therefore the mmf required for rotor teeth would not be excessive");

fprintf(fp, "\nThe bars are skewed by one slot pitch extending the bars by about 20mm beyond the core one each side and taking 10 mm as increase in the length because skewing");

Lbr=(L*1000)+40+10;
fprintf(fp, "\nLength of each bar is %0.3f mm", Lbr);
Rbr=(0.021*(Lbr/1000))/Abr;

```



```

/*printf("\nTotal rotor copper loss is %0.3f W",PLC2);*/
slip=(PLC2/(P*1000))/(1+(PLC2/(P*1000)));
/*printf("\nSlip atr full load %0.3f percent",(slip*100));*/

/*rotor core*/

printf("\t\t\t\tROTOR CORE");
fprintf(fp,"\n\n\n\n\t\t\t\tROTOR CORE");
printf("\nDepth of rotor core is taken equal to that of stator core. The
area and the flux density in the rotor core is the same as in the stator core");
Drc=Dcs1;
printf("\nDepth of rotor core is %0.3f mm",Drc);
Drcia=Dr-(2*Drc)-(2*Dbr1);
printf("\n Inner diameter of rotor lamination %0.3f mm",Drcia);
fclose(fp);
}

int main()
{
    md();
    sdm();
    rdt();
    return 0;
}

```

```
here x designprog.c x
1  #include <stdio.h>
2  #include <conio.h>
3  #include <math.h>
4  #define pi 3.141592654
5  float ns,nd,p_f,P,n,p,Q,m,Es,f,Bav,ac,Co,Kw,H,a,b,c,D,L,t,Wd,Ki,Li,Ns;
6  float F,Kws,qs,Ss,yss,Ts,Tc,Ts1,T,Zss,Cs,Kp,Kd,Kws1;
7  float Is,Id,As,As1,d,d1,wire,cov;
8  float Os,Or,Wt,Fd,wsd,sd,sld,Wss,Lip,swe,dss,slackd,slackw,dss1,wsd,sw,Wss1,slw,AA,Lmts;
9  float Fs,Fds,Acs,Dcs,Do;
10 float Ibr,Idr,Abr,Dbr,Wbr,Wbr1,Dbr1,AAbr,Wbrt,Fbrd,Lbr,Rbr,PLC;
11 float Ier,Ierd,Aer,Ted,Ded;
12 float Deo,Dei,Dem,Red,PLC1,PLC2,slip;
13 float Drc,Drcia;
14 float ratio1,ratio2,ratio3,Kcs,Kgss,Kcr,Kgsr,Kgs,Kcd,Kgd,Kg,lge,Agp,Bg,ATs;
15 float Wts,Ats,Bts,ATs1,ats;
16 float Acs1,Bcs,Lcs,ATs2,ats1;
17 float Wrt,Art, Brt,ATs3,ats2;
18 float Acr,Bcr,atr,Lcr,ATs4,TATs,Im;
19 float West,Bstmax,Irlst,Isrlst;;
20 float Isrlsc,Pmsc,Wesc,Irlsc,TIrls,FWI,FWI1,Tnll,Il,Inl,p_fnl,ap_fnl,ap_fnl1,AIrls;
21 float mo=(4*pi), Gss;
22 float xs,sldr=0.5,slackdr=0,swer=1.5,Lipr=0.5,Grr,Gsr,TG;
23 float Lov,xo;
24 float Xm,as,ar,Xz,TX;
25 float Zlss,IsC,p_fsc,asc,asc1;
26 float R,PSCL,Rrs,Rt;
27 float OPfl,IPfl,eff;
28 float lg,Dr;
29 float Dcs1,Sr,ysr;
30 int key;
31 FILE *fp;
32 /* main dimension*/
33 void md()
```

Output

```
#include <stdio.h>

MAIN DIMENSIONS

Enter the power(p) in kW:3.75
Enter the full load efficiency(n):0.8
Enter the power factor(p_f):0.8
For good power factor ,L/t should be between 1 to 1.5.
Diameter of the core D=0.139 m.
Length of the core L=0.131 m.
The value of Pole Pitch t=0.109 m.
Want to modify these values ?
1-for 'yes' and 0-for 'no':_
```

```
Enter the modified diameter in m:0.139
Enter the modified core length in m:0.131
The modified pole pitch in m is :0.109
Length of core is greater or equal to 120
Radial ventilation duct is necessary.
                                STATOR DESIGN

WINDING
Enter the input voltage(V):
```

Select the connection type.

1-Star.

2-Delta.

:1

The conductor per slot is 45.

The value of stator per phase is 181 and the calculated turn per phase is 180 ie very near

.
So no modification of value of BaV.

CONDUCTOR SIZE

Area of the stator conductor is 2.114 mm^2 .

The power is 3.75 kw. So conductor type is round.

Diameter of the stator conductor is 1.641 mm.

SLOT DIMENSION

Now, each conductor consists of 1 wire outside diameter 1.325 mm
n.

Number of conductor per slot is 45 and 45 of wires/strips in slot.

Slot depth without slack is 25.375 mm

Slot width without slack is 7.625 mm

Flux density in teeth (max value is 1.7 Wb/mm^2) is 0.902 Wb/mm^2

Want to modify the flux density?

1-'yesy' and 0-'no'

```
"C:\Users\PRIYAMVADA BHATNAGAR\Desktop\PRIYA FOLDER\WINTER SEM 2017 -2018\Design of electrical apparatus\designprog.e...
Slot depth without slack is 25.375 mm
Slot width without slack is 7.625 mm
Flux density in teeth (max value is 1.7Wb/mm^2) is 0.902 Wb/mm^2
Want to modify the flux density?
1-'yesy' and 0-'no'0
STATOR CORE
Flux in stator core 0.003003 Wb
Assuming a flux density of 1.20 Wb/mm^2
Area of the stator core 0.002503 m^2
Depth of stator core 0.022982 mm\nThe depth of core used is 22.981911 mm
Outer diameter of stator laminations 1334.059 mm
ROTOR DESIGN
AIR GAP
Area of rotor bar 44.733 mm^2.
ROTOR SLOTS
END RING
End ring current is 555.313 A
MEAN DIAMETER OF RING
Outer diameter of end ring is 127.927 mm
Inner diameter of end ring is 127.927 mm
Mean diameter of end ring is 127.927 mm
ROTOR CORE
Depth of rotor core is taken equal to that of stator core. The area and the flux density in the rotor core is the same as in the stator core
Depth of rotor core is 22.982 mm
Inner diameter of rotor lamination 92.096 mm
Process returned 0 (0x0) execution time : 118.453 s
Press any key to continue.
```

Conclusion

The design of motor design program for educational purposes was the motivation behind the study. The scope of this project is featuring c programming for the design of three phase induction motor in its basic form useful for designing and in teaching field . The present work has concentrated on the design of standard induction motor which can be extended for designing energy efficient machines as a future scope.

References

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