# Chapter 1

1. **A Copper bar with a diameter of 1.2cm and length 20cm is insulated with micanite which fits tightly around the bar and into the rotor slot of induction motor. Thickness of the micanite tube is 1.5mm and thermal resistivity is . Calculate the loss that will pass from copper bar to iron for a temperature difference of C maintained between them.**

**Solution:**

Diameter of Copper Bar, D = 12mm = 12\*m

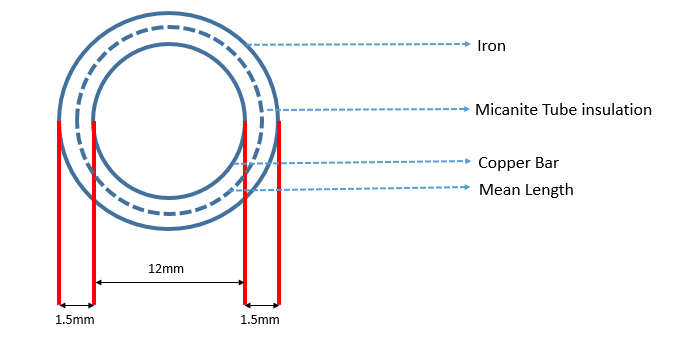
Thickness of Micanite Tube, t = 1.5mm = 1.5\*m

Thermal Resistivity () =

Temperature difference, () = C

Length of Copper bar, L = 0.2m

Loss that will pass from copper bar to iron, = ()/



Thermal Resistance, =   
Surface area of insulation s = π\*(D + t)\*L = π\*(12+1.5)\*\*0.2 = 8.4823\*

=  = 11.4147

= = 17.6715 W

1. **A 230V, 2.5KW single element resistor is made of a cylindrical nichrome wire. The temperature rise of strip should not exceed C over the ambient temperature of C Determine the length and diameter of strip assuming coefficient of emissivity() 0.9, radiating efficiency = 1 and resistivity of nichrome wire() as 0.424 .**

**Solution:**

Voltage = 230V; Power() = 2.5KW

Temperature of nichrome wire, = 1200 + 20 = C (Converted to absolute temperature as 1493K)

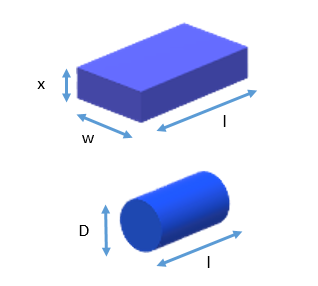
Temperature of Ambient medium, = C (Converted to absolute temperature as 293K)

Coefficient of emissivity () = 0.9

Radiating Efficiency () = 1

Stefan's Boltzmann constant,

Heat dissipated from material,



Resistance of nichrome wire, R = ()

R = 21.16

R = ()/A

A = (

------------------------------------------------------------------------------------------------- (1)

Total heat radiated,

= 3.1266\* ----------------------------------------------------------------------------------------- (2)

Solve eq. (1) and eq. (2),

D = 0.0726m;L = 0.0430m

1. **The inner dimensions of the former field coil of a DC Generator are 150mm \* 250mm. The former is 2.5mm thick. Calculate the heat conducted across the former from winding to core if there is an air space 1mm wide between the former and the pole core. The thermal conductivities of former and air are 0.166 and 0.05W/m- , respectively. The winding height is 200mm and the temperature rise is 40 .**

**Solution:**

Thickness of field coil, = 2.5mm

Thickness of air space, = 1mm

Winding height = 200mm

Thermal conductivity of the field coil, = 0.166W/m-

Thermal conductivity of the air, =0.05W/m-

Temperature rise, = 40

Heat conducted across the field coil, = (

Thermal resistance, = + (i.e., sum of thermal resistance of field coil and air coil)

=

=

=

= (2.5\*/ (0.166\*0.16)

= 0.094

= (1\*/ (0.05\*0.16)

= 0.125

= 0.094 + 0.125 = 0.219

= (40/0.219) = 182.6484

1. **Calculate the heating time constant of 10KVA transformer during a heat run test, if the temperature rise after one hour and two hours is found to be 35 and 47.5, respectively.**

**Solution:**

Temperature rise of transformer after one hour = 35

Temperature rise of transformer after two hour = 47.5

Temperature Rise,

At t=1, 35 = ---------------------------------------------------------------------------------------- (1)

At t=2, 47.5 = -------------------------------------------------------------------------------------- (2)

Div eq(2) and eq(1)

1. **During a heat run test of a 100KVA transformer, the temperature rise after one hour and two hours are found to be 24 and 34, respectively. Calculate the heating time constant and final steady state temperature rise. If the cooling is improved by using an external fan so that the rate of heat dissipation is increased by 18%, find the new KVA rating for the same final temperature rise. Assume the maximum efficiency occurs at 80% of full load and unity p.f.**

**Solution:**

Transformer power output = 100KVA

Maximum efficiency, = 80 %( efficiency at full load,)

Temperature rise after one hour = 24

Temperature rise after two hour = 34

Increase in rate of heat dissipation when cooling is employed by external fan = 18%

Temperature Rise,

After one hour:

24 = ---------------------------------------------------------------------------------------------------- (1)

After two hours:

34 = ---------------------------------------------------------------------------------------------------- (2)

= - 0.87562

Substitute T

34 =

= (34/0.827) = 41.1125

Allowable losses = 1.18 \* (Total losses at full load)

Total losses at full load =

, we know

= 1.5625

Allowable losses = 1.18\*(1.5625+) = 3.02375

Allowable copper loss = 3.02375 - = 2.02375

Allowable copper losses = 2.02375\*

Copper losses at this output, 1.2952 =

= 1.2952

x = 1.1380

New output = x (100KVA) = 1.1380\*100KVA = 113.80KVA

------------------------------------------------------------------------------------------------------------------------------------------ **DC Machine Output Equation based on the ratings and dimensions**

Output Power developed is given by:

|  |
| --- |
| - Power Developed by armature in KW.  E - Generated emf  - Armature Current |

The Above equation will be expressed based on main dimensions, specific electric and magnetic loading with speed of operation.(i.e., = K\*() where K is a constant)

**Specific Magnetic Loading ():** The total flux per unit area over the surface of the armature periphery. It is also called as average flux density.

|  |
| --- |
| = |

**Specific Electric loading (ac):** The number of armature conductors per meter of armature periphery at the air gap.

|  |
| --- |
|  |

Where,

* is the Diameter of the machine(Armature)
* is the Length of the machine(Core)
* is the number of poles in the machine
* is the flux
* - current in each conductor
* - number of armature conductor

**Choice of Specific magnetic loading ():**

1. Flux density in teeth: If a high value of flux density is assumed for air gap, the flux density in armature teeth also becomes high. The maximum value of flux density in the teeth section should not exceed a value of 2.2 Wb/ because at higher flux density
   1. increased iron losses and
   2. Higher ampere turns requires for passing the flux through teeth leading to increase copper losses and cost of copper.
2. Frequency: the frequency of flux reversal in the armature is given by f = np/2. Higher frequency will result increased iron losses in the armature core and teeth. So there is a limitation in choosing higher for a machine having higher frequency.
3. Voltage: For high voltages, Machine space required for insulation is large. Thus for a given diameter less space is available for iron leading to narrower teeth. Therefore lower value of has to be taken otherwise teeth flux density increases beyond the permissible limit.
   1. Value of varies from 0.4 to 0.8 Wb/.

**Choice of specific electric loading ():**

1. Temperature rise: A higher value of ‘ac’ results in a high temperature rise of windings. A high value of ‘ac’ can be used for machine using insulating material which withstand high temperature rise.
2. Speed of machine: for high speed machine, the ventilation is better and greater losses could be dissipated. Thus a higher value of ‘ac’ can be used for higher speed machine.
3. Voltage: machine with high voltage require large space for insulation, therefore there is less space for conductors. For high voltage machines use small value of ampere conductors per meter.
4. Size of machine: in large size machine there is more space for accommodating copper. Therefore high value of ‘ac’ could be used.
5. Armature reaction: if using high value of ‘ac’, armature mmf becomes high. This means under loaded condition there will be grater distortion of field form resulting in a large reduction in the value of flux. To compensate this field ampere turns are needed to be increased. Thus overall cost of copper in the machine will increase.
6. Commutation: a high value of ‘ac’ means either ampere conductors used are more or diameter is small. Reactance voltage increases with high ampere conductors. With small diameter, deeper slots are used. Deeper slots also give higher reactance voltage. Higher reactance voltage results in bad commutation. Thus using higher ‘ac’ affects the commutation badly.
   * The value of ‘ac’ varies from 15000 to 50000 ampere conductors per meter.

**Generated emf of a DC Machine Equation:**

|  |
| --- |
|  |

Where,

* is speed in r.p.s
* is Number of parallel paths
* is the number of poles in the machine
* is the flux
* - number of armature conductor

**Total Armature Current:**

|  |
| --- |
| **=** |

**Power Equation:**

Substituting the Generated emf and Total armature current in output power equation

|  |  |  |  |
| --- | --- | --- | --- |
| |  |  |  | | --- | --- | --- | |  | |  | | --- | |  | | |

## AC Machine Output Equation based on the ratings and dimensions

Output Power developed in 3- machine is given by:

|  |
| --- |
| Generated emf in one phase  Armature Current  Power Developed |

The Above equation will be expressed based on main dimensions, specific electric and magnetic loading with speed of operation.(i.e., = K\*() where K is a constant)

**Generated emf of a DC Machine Equation:**

|  |
| --- |
| = |

Where,

* - Frequency
* - Flux
* - Total Number of Turns per phase
* - Winding Factor()
* - No of poles
* - Speed in r.p.m
* - Speed in r.p.s

Current in each conductor ()

|  |
| --- |
| **=** |

Where,

* - current in each conductor
* - number of armature conductor
* is Number of parallel paths

Total Number of conductors,=

Consider A = 1,

**Coil Factor or pitch factor ()**

The Ratio of emf generated in short pitch coil to the emf generated in full pitch coil. It is denoted by and its value is always less than unity. This factor basically represents the effect of short pitch winding on generated emf across the winding terminals of electrical machine.

Let coil have a pitch short by angle electrical spaced degrees from full pitch and induced emf in each coil side,

* If full pitched, total induced emf in coil would be.
* When short pitched by an electrical angle , resultant emf is sum of phasor voltages

|  |
| --- |
| *For order harmonic,* |

**Distribution Factor or the Breadth Factor ()**

The ratio of the actual voltage obtained to the possible voltage if all the coils of a polar group were concentrated in a single slot. It is denoted by and is given by the equation shown below. In a

Concentrated winding, each phase of a coil is concentrated in a single slot.

No of slots per pole per phase = q

Induced emf in each coil side =

Angular displacements between slots =

Resultant emf =

|  |
| --- |
| *(For order harmonic)* |

**Specific Magnetic Loading ():** The total flux per unit area over the surface of the armature periphery. It is also called as average flux density.

|  |
| --- |
| = |

**Specific Electric Loading (ac):** The number of armature conductors per meter of armature periphery at the air gap.

|  |
| --- |
|  |

Where,

* is the Diameter of the machine(Armature)
* is the Length of the machine(Core)
* is the number of poles in the machine
* is the flux
* - current in each conductor
* - number of armature conductor

Output Power in terms of above presented equations,

Substituting, in power equation, we get

|  |  |
| --- | --- |
| |  | | --- | |  | |