ENGINEERING ACADEMY

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Machine Winding

Hand Written Notes

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About

Mr. R. K. Raman is presently CEO and Managing Director of Engineering Academy Dehradun (EAD), He obtained his B. Tech. from H.N.B. Garhwal University, M. Tech. from SLNIT Sangrur Punjab, more than 40 students completed M. Tech. Thesis under the guidance of Mr. R. K. Raman.

He has involved in teaching since last 10 years in various engineering collage in Dehradun and engineering academy Dehradun.

He has also giving an online platform of technical and not tech education in YouTube as well as in EAD online classes application, where he delivered more than 3K video lectures, most of the lectures are based on the Electrical Stream subjects like; Basic Electrical, Power System, Machine, Power Electronics, Measurement & Instrumentation etc.

By the help of online lectures more than 5K students selected in in different government exams.

R.K. RAMAN
MD & CEO EAD Group
March, 2022

MACHINE WINDING

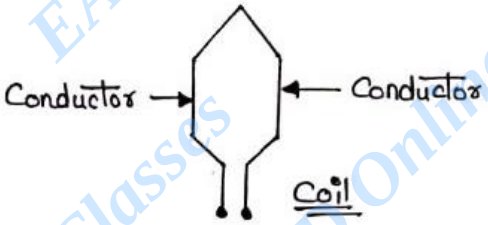
-: Winding :-

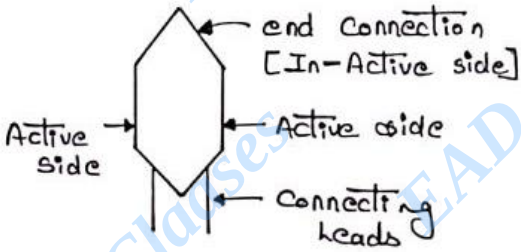
Generator :- When a conductor cuts magnetic field or magnetic field cuts a conductor then a voltage induced in the conductor.

Motor :- When a current carrying conductor placed in a magnetic field then a force act on that conductor.

Winding :- When we wrapped up many wires [Conductor] in a systematic way according to our need, then it is called winding.

Coil :- When conductors are wrapped up in a fixed shape, are called coil.





Active Side :- It is inside the slot & comes in a contact with magnetic field & voltage induced in this.

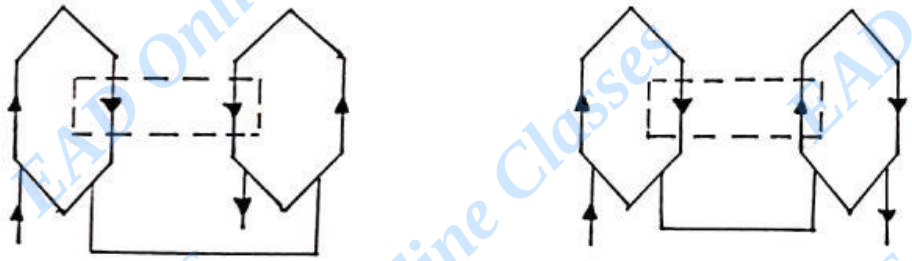
Inactive Side :- It is placed outside the slot & did not comes with a contact with magnetic field so no voltage induce in it. It is a connection between active leads.

Connecting Leads :- Winding is made up of many coils. We can joins the coils with each-other according to our need with the help of connecting lead.

Coil Group :- When more than one coil are connected in such a way that after flowing current in this, one becomes north pole and another becomes south pole then it is called coil group.

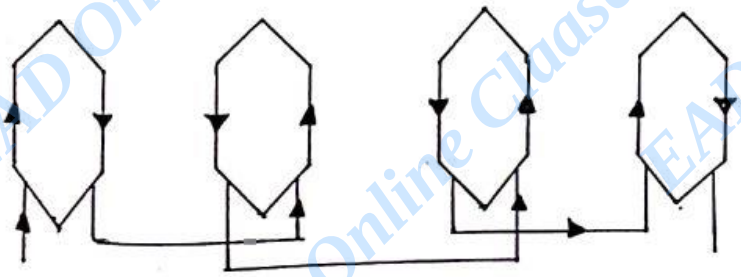
$$\text{Coil group} = \frac{\text{Total Numer of Coils}}{\text{Total Pole} \times \text{Phase}}$$

Group Connection :- When more than one coil group of same phase are connected together then it is called Group Connection.

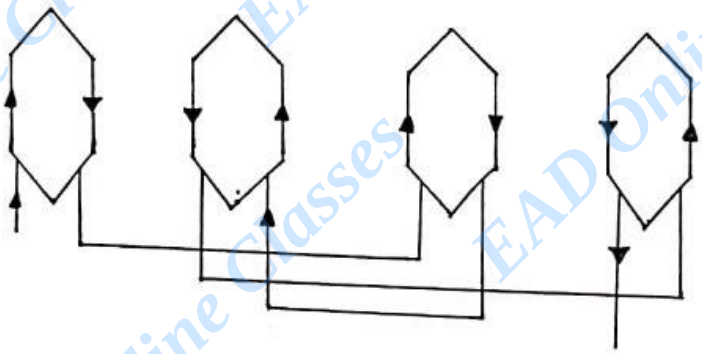


Group connection can be made by two types :-

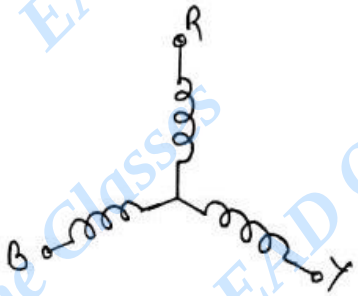
Adjacent Group Connection :- When more than one coil group of same phase are connected in such a way that only adjacent coils ~~making~~ makes group then it is called adjacent group.

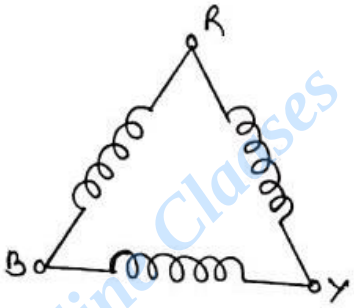


Alternate Group Connection:- When more than one coil group of same phase are connected in such a way that except one make group then it is called Alternate Group Connection.



Phase Connection:- When one phase is connected with another phase, then it is called phase connection.

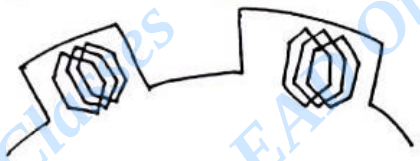




Half Coil Winding:- When total number of coils be half of the total number of poles then it is called Half coil winding.

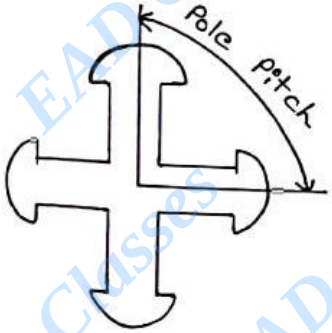
Full Coil Winding:- When total number of coils is equals to total number of poles then it is called Full Coil winding.

Single Layer Winding :- When only one side of one coil is put on one slot then it is called single layer winding.



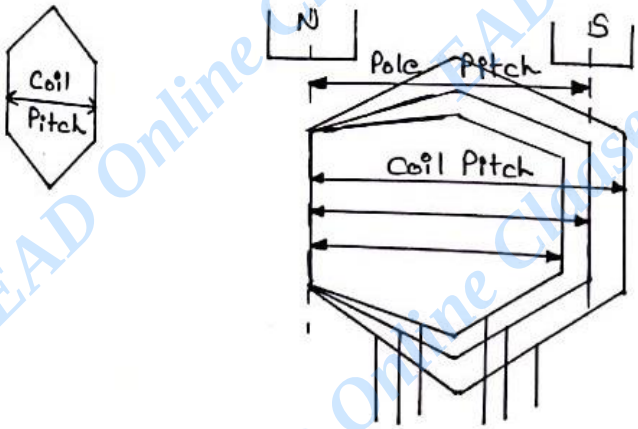
Double Layer Winding :- When two side of two coils are placed on one slot, then it is called double layer winding.

Pole Pitch :- Distance between two adjacent poles is called pole pitch.



$$\text{Pole Pitch} = \frac{\text{No. of slots}}{\text{No. of Poles}}$$

Coil Pitch :- Distance between both active sides of a coil is called coil pitch.

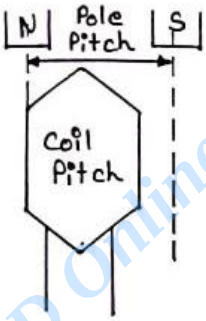


$$\text{Pitch Factor} = \frac{\text{Coil Pitch}}{\text{Pole Pitch}}$$

$$\text{Coil Pitch} = \frac{\text{No. of slots}}{\text{No. of Pole}}$$

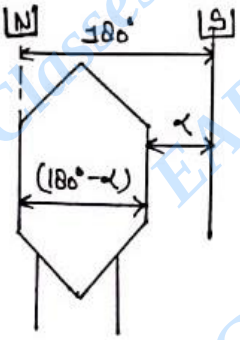
Coil Pitch can be done by Three ways:-

[1] Short Pitch Winding:- When coil pitch is less than pole pitch or pitch factor is less than one then it is called short pitch winding.



$$\text{Pitch factor} = \frac{\text{Coil Pitch}}{\text{Pole Pitch}} < 1$$

The angle between both coil sides is less than 180° electrical.
If coil pitch is short at α degree angle, then



$$k_c < 1$$

Qn:- To eliminate the 5th order harmonic, the winding short by which angle?

$$\Rightarrow \alpha = \frac{180^\circ}{5} = 36^\circ$$

$$\text{Pitch factor} = \text{Coil Span factor} = k_c = \cos\frac{\alpha}{2}$$

Advantages of short Pitch winding :-

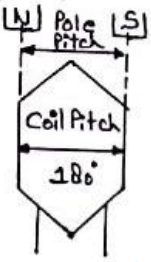
(1) Saving in conductor material
(2) Harmonics is reduced.

for n-order harmonics, $k_{c(n)} = \cos\frac{n\alpha}{2}$ $\quad \alpha = \frac{\pi}{n}$

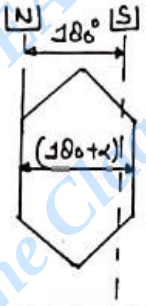
Disadvantages :-

(1) Total induced voltage is reduced.

[2] Full Pitch Winding :- Pitch factor is one for this winding.



[3] Long Pitch Winding :- Pitch factor is greater than one for this winding.



* Angle between the both active side of coil is greater than 180° electrical.

$$\text{Pole Pitch} = \frac{\text{No. of conductor}}{\text{No. of Pole}}$$

$$\text{Slot Pitch} = \frac{\text{पृष्ठ पिच} - 1}{\text{कुण्डली पार्श्व/सांचे}} = \frac{\text{सांचे}}{\text{ध्रुव}} - 1$$

Qn:- A 2 Pole motor has 12 armature slots. Find out slot Pitch?

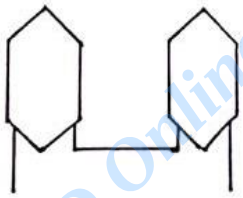
=> Slot Pitch $= \frac{12}{2} - 1$

Slot Pitch $= 5$

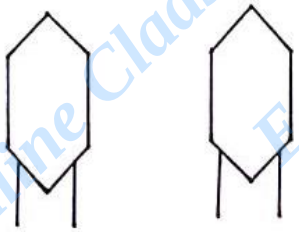
Qn:- A 4 Pole motor has 24 slots. Find out the slot pitch of armature which have 48 coil sides.

=> Slot Pitch $= \frac{11-1}{48/24} = \frac{10}{2} = 5$

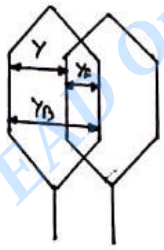
Closed Type Winding :- It is used in dc machines.



Open Type Winding :- It is used in AC Machines



Front Pitch:- It is the distance between the second conductor of one coil and the first conductor of the next coil.



Y_F → Front Pitch
Y_B → Back Pitch

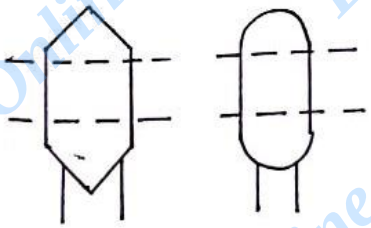
Commutator Pitch:- It is the distance between the commutator segments to which the two ends of a coil are connected.

Back Pitch:- It is the distance between the two sides of back coils.

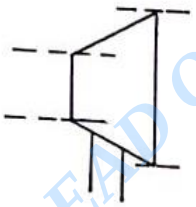
Resultant Pitch:- It is the distance between the first side of first coil and second side of second coil.

Types of Coil:-

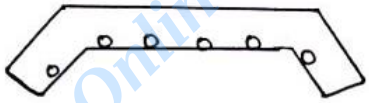
[1] Mush Coil:-
* Length of both active sides is equal.
* It is prepared on wooden frame.
* It is prepared in 'V' & 'U' shape.

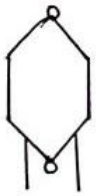


[2] Skew Coil:- * Length of both active side of coil is unequal.
* Good cooling is obtained.

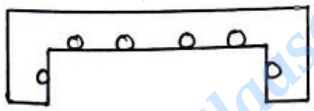


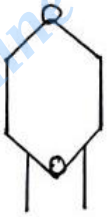
[3] Diamond Coil:- * This is done for large machines.
* Cooling is also good.
* At first, simple coil is made & then turn over this from both sides.



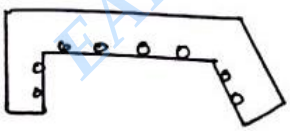


[4] Invalute Coil:- * It is done by with the help of Rod & plate.
* It is done on frame and by dragging from the side we can provide a suitable shape.





[5] Combination Coil:- * It is made by the combination of diamond coil & Invalute coil.
* both the Inactive sides are different.



Winding Conductor Material :-

Aluminium :-

⇒ Conductivity is about 60% of copper.
⇒ Less mechanical strength
⇒ Less specific gravity [2.7 gm/cc]. So the weight is less for equal volume.
⇒ It is used in long transmission line.
⇒ Rarely used in winding.

Copper :-

⇒ It has good conductivity
⇒ More mechanical strength
⇒ Weight is more because of high specific gravity [8.9 gm/cc]
⇒ Area of wire is less.
⇒ Plates & rods can be easily made by this.
⇒ Nowdays, it is mostly used for winding in machines. [12 S.W.G. to 48 S.W.G.]

According to insulation on wires it can be divided into followings :—

[i] S.C.C. [Single Cotton Covered Conductor] :-

* In this, a layer of cotton thread is done on the copper wire.
* 16 SWG to 40 SWG
* It can be purchased according to weight.

[ii] D.C.C. [Double Cotton Covered Conductor] :-

* In this, two layer of cotton thread is done on the copper wire.

* 16 SWG to 48 SWG.

[3] S.S.C. [Single Silk Covered Conductor]:-

* In this, a layer of silk thread is done on copper wire.
* 16 S.W.G. to 48 S.W.G.

[4] D.S.C. [Double Silk Covered Conductor]:-

* In this, two layers of silk thread is done on copper wire.
* 16 S.W.G. to 48 S.W.G.

[5] Enamold Vanish:-

* In this, a special type of varnish is done on copper wire.
* 6 S.W.G. to 48 S.W.G.

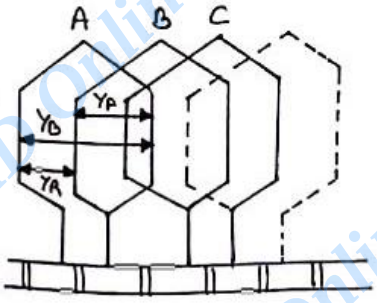
DC Winding:-

Winding is done by two ways:-

1. Lap Winding
2. Wave Winding

1. Lap Winding:-

* It is used for high current & low voltage.
* Number of parallel path is equal to number of poles.

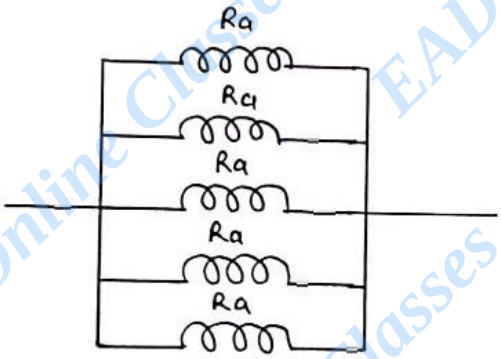


$$Y_R = Y_B - Y_F$$

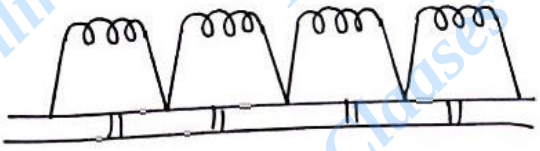
* In lap winding, Y_B and Y_F should be odd.
* Coil pitch & pole pitch should be equal.
* Difference of Y_B and Y_F should be 2.

$$Y_R = Y_B - Y_F = 2$$

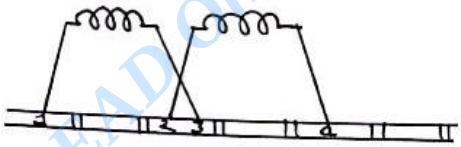
* Commutator pitch should be unity.
* Number of commutator segments is kept greater than number of coils.



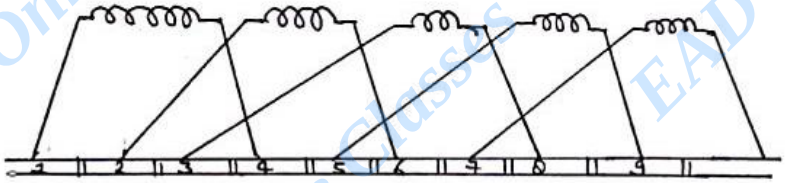
(i) **Simplex Winding :-** In this winding, both the sides of coil comes on one slot or we can say that where the end of first coil is ended from there the end of the second coil is started. In this, number of coils is equal to the slots and segments. It is done for small and medium machines.



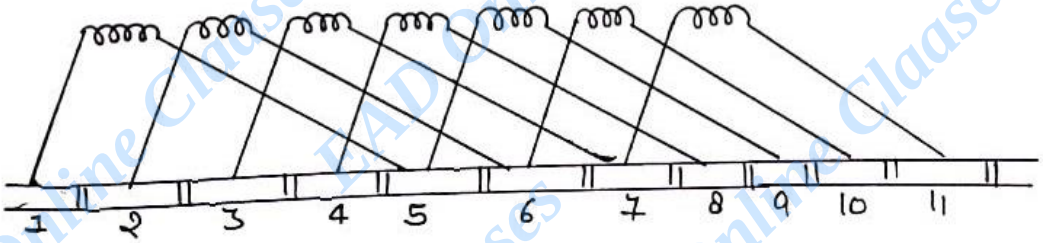
(ii) Duplex Winding :- In this winding, difference of two segment is kept between each coil sides. In this, brush touches the segment. In this winding current flow is two times of simplex winding.



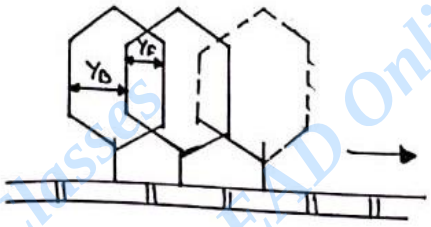
(iii) Triplex Winding :- In this winding, difference of three segment is kept between both the sides of coil. each brush touches three segment and in this winding current flow is three times of simplex winding.



(iv) Quadruplex Winding :- In this winding, the difference between two coil sides is four segment. In this each brushes touches four segment then in this winding current flow is four times of simplex winding.



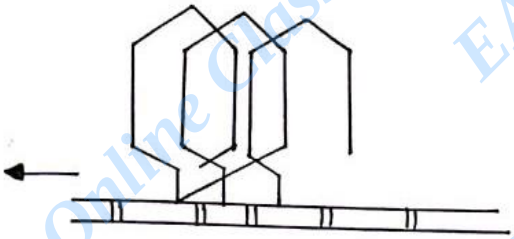
Progressive Type Winding :-



$Y_B > Y_F$

* It is done towards right side.

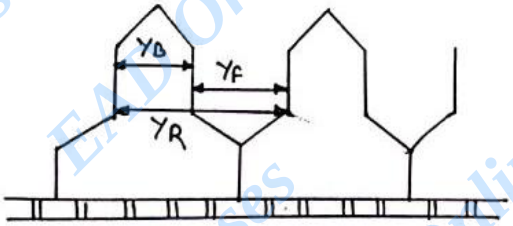
Retrogressive Type Winding :-



$Y_F > F_B$

* It is done towards left side.

Wave Winding :- In this winding, whatever be the poles but parallel path are only two.



$Y_R = Y_B + Y_F$

$$\text{Average Pitch} = \frac{Y_B + Y_F}{2}$$

* It is used for High voltage and low current.
* Coil pitch & pole pitch are equal for this.
* In this, Y_B and Y_F can be equal or has a difference of 2.

$$Y_C = \frac{\text{No. of segments} \pm 1}{\text{Pairs of Poles}}$$

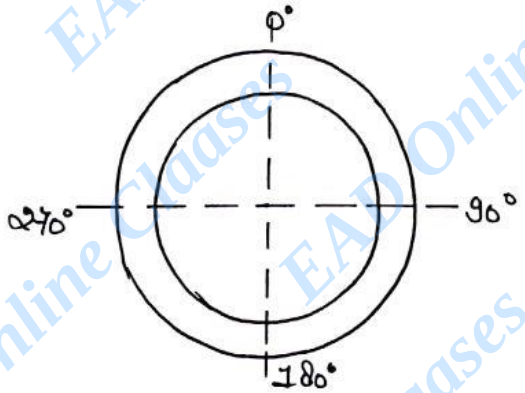
* For two pole machine, lap & wave winding are done by same ways.

Difference between lap winding & wave winding :-

Lap Winding	Wave Winding
(1) $A = P$	(1) $A = 2$
(2) Parallel Winding	(2) Series Winding
(3) High Current & less Voltage	(3) High voltage & less current
(4) Coil overlap	(4) Coil never be overlap
(5) $Y_R = Y_B - Y_F$	(5) $Y_R = Y_B + Y_F$
(6) $Y_B - Y_F = 2$	(6) $Y_B = Y_F$, $Y_B - Y_F = 2$

Methods of putting brush on commutator :-

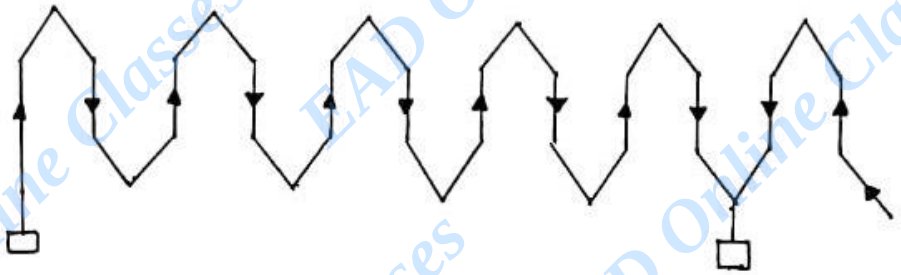
1. **Degree Method :-** For two pole machine, the angle of 180° is kept between brush.



[4 Pole → 90°]

2. **Ring Method :-** Machine has 12 slots and 12 segments and 12 coils are in 12 slots then total coil side is 24. In which current is downward they comes

Under North pole and in which current is upward, they comes under south pole. In which point current is same in both direction, the brush is fixed there.

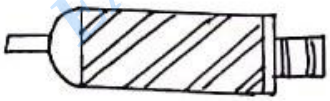


$$\theta_{electrical} = \frac{P}{2}\theta_{mechanical}$$

Armature Winding in DC Machine:-

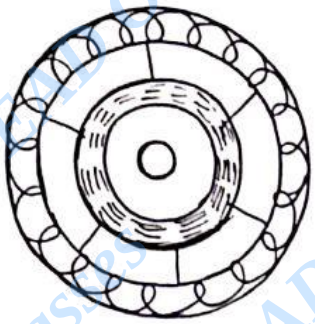
(1) **Ring Type:-** In this, the wire is takes out from the inside of the ring and wrapped. It is a difficult task. In this, not all wires comes with a contact with magnetic field. This type of machines have lower efficiency.

(2) **Drum Type:-**



[3] Large Armature :- It is used for large machine.

* It should not be too heavy so the inner part is kept empty.



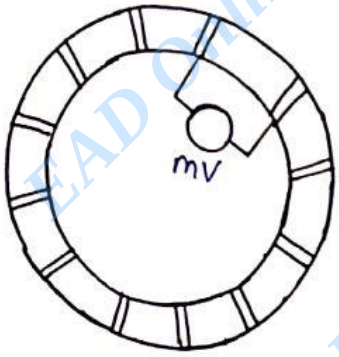
Testing :-

1. Open Circuit Testing
2. Short Circuit Testing
3. Earth or leakage Testing

[1] Open Circuit Testing :-

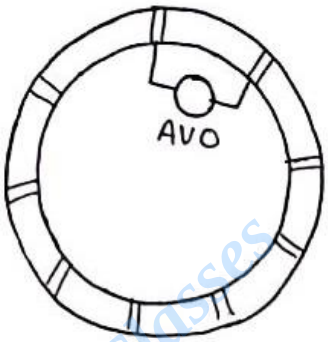
→ कोई Conductor कहीं से टूट ना जाए,
→ ज्यादा तापमान होकर जल गया हो,
→ Commutator segment से टूट गया हो,
→ Commutator segment पर लगा load पिघल गया हो,

Mili Voltmeter	AVO	Test Lamp



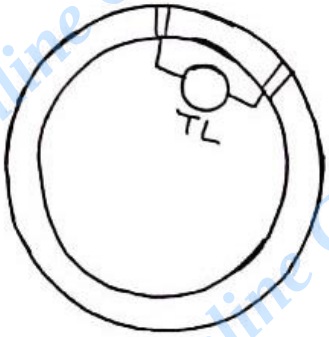
यदि mili voltmeter equal voltage दिखाता है तो सही है अन्यथा वाइंडिंग open है।

(2)



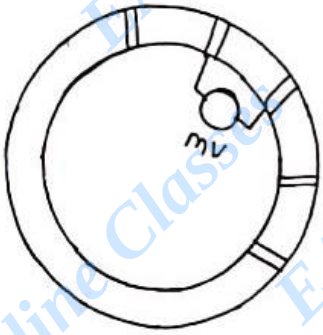
यदि यह कुछ Resistance नापता है तो सही है और यदि यह कोई प्रतिरोध नहीं दिखाता है तो वाइंडिंग Open है।

(3)



यदि Test Lamp Bright करे तो वाइंडिंग सही है नही तो open है।

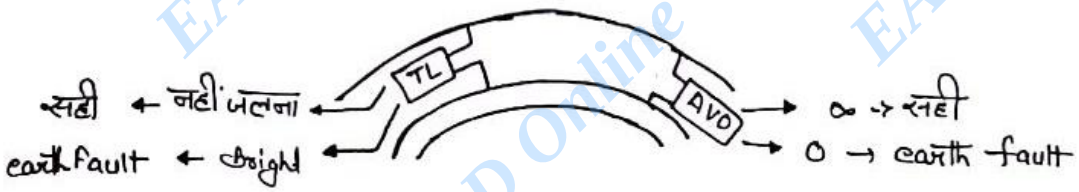
Short Circuit Test :- (1) यदि प्रत्येक segment पर वोल्टेज समान हो तो सब ठीक है नहीं तो जिस segment पर वोल्टेज बाकी से कम प्राप्त होगी वह आपस में शॉर्ट है।



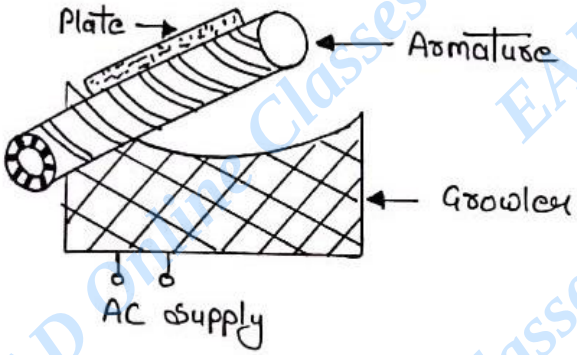
(2) AVO से जिन भी segments पर प्रतिरोध बाकी से कम होगा वह आपस में शॉर्ट है।

(3) Test Lamp जिन भी segments पर बाकी से ज्यादा bright करेगा वो आपस में शॉर्ट है।

Earth or Leakage Testing :- (1) AVO (2) Test Lamp



Growler Method:- DC machine winding is done by this method. With the help of growler, open circuit testing, short circuit testing, and earth fault testing is performed. We gave AC supply to this and growler winding works as primary winding of transformer. A cage is cutted on the upper side of growler in which armature winding of dc machine is placed. Now armature winding works as secondary winding of transformer.



Short Circuit Test:- A milivoltmeter is fixed between two commutator segment. If the voltage is same at all segments then winding is correct or at which segment voltage is less, they are shorted with each other. After giving supply to the growler, if plate is attract towards slot or any movement is happen then these segments are short with each other.

Open Circuit Test:- If a milivoltmeter gives reading between two segments then it is ok otherwise it does not give any reading then winding is open.

Earth fault:- One side of milivoltmeter is connected to segment & the other one is connected with shaft. If milivoltmeter give some reading then it is ok

otherwise no reading is given then winding in touch with the body.

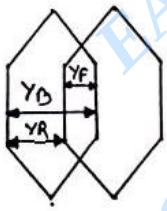
Series Lamp Method:—

(1) Open Circuit Test
(2) Short Circuit Test
(3) Earth Circuit Test

In this method, a lamp is connected in series with winding. If lamp is evenly brights then winding is not short circuited or if lamp brights more then winding is short circuit. If lamp does not brights then winding is open. Now one side of lamp connected with segments and other one is connected with the shaft. If lamp becomes bright then there is earth fault.

Voltage Drop Method:—

A low dc voltage is applied at carbon brush and mili voltmeter is connected with segments. If the voltmeter gives equal voltage on all segments then it is ok otherwise which segment gives low voltage on voltmeter then they are short circuited with each other. Which segments gives high voltage on voltmeter then thy are open circuited.



Lap:- $[Y_R = Y_B - Y_F]$

Wave:- $[Y_R = Y_B + Y_F]$

$Y_B > Y_F$ → Progressive

$Y_F > Y_B$ → Retrogressive

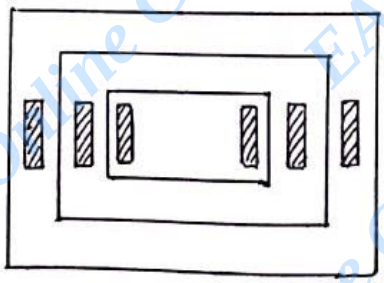
Average Pitch = $\frac{Y_B + Y_F}{2}$

Pitch factor = $\frac{\text{Coil Pitch}}{\text{Slot Pitch}}$

AC Winding :-

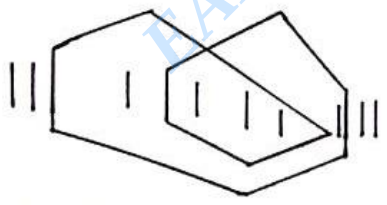
1 Basket Winding :- इसका आकार बुनी हुई टोकरी के जैसा होता है इसीलिए इसे Basket Winding कहते हैं, इसे इस तरह से बुना जाता है कि एक कॉइल दूसरी के ऊपर होती है तथा अगली बार दूसरी कॉइल ऊपर होती है, इसमें पिच समान होती है तथा इसे 3-ϕ Induction Motor में करते हैं।

2 Concentric Winding :-



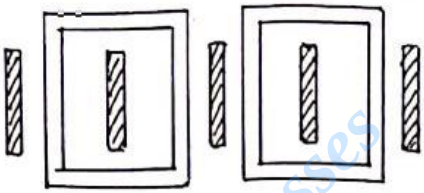
इसमें एक ही क्वाइल ग्रुप की प्रत्येक क्वाइल का एक ही केन्द्र होता है, इसमें पिच समान नहीं होती है, इसमें क्वाइल एक - दूसरे के ऊपर चढ़ी नहीं होती है, यह करने में मुश्किल होती है, इसमें कूलिंग के लिए ज्यादा स्थान होता है।

3 Skein Winding :-

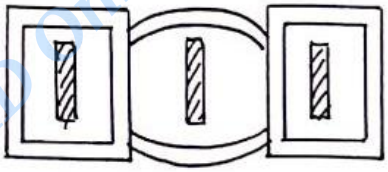


इसमें लम्बे व मोटे क्वाइल को स्लॉट में एक स्लॉट में एक के बाद एक भरते रहते हैं, इसे ज्यादातर 1-ϕ Induction motor में use करते हैं।

④ Flat Loop Winding :- इसमें दोटी-2 क्वाइल को इस प्रकार लेते हैं कि यह एक-दूसरे को आपस में touch ना करे. इसे 1-ϕ Induction Motor पंखे के लिए use करते हैं.

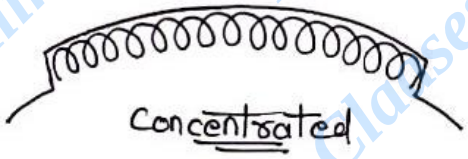


⑤ Chain Winding :- इसमें क्वाइल एक-दूसरे के ऊपर चढ़ी होती है. इसमें प्रति पोल प्रति फेज एक से ज्यादा होता है. यदि एक ही क्वाइल ग्रुप की क्वाइल का केन्द्र एक हो तो इसे Concentric winding कहते हैं.

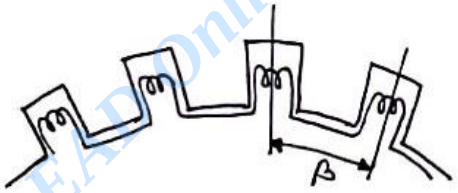


Dummy Coil :- इसे slots में मात्र भरा जाता है लेकिन इसे किसी supply से जोड़ा नहीं जाता है. इसे करने से मशीन में एक यांत्रिक संतुलन हो जाता है.

Distributed Winding :- जब हम प्रति पोल प्रति फेज कई slots काटते हैं तथा उनमें वाइंडिंग करते हैं तो यह distributed winding कहलाती है.



$$m = \frac{\text{slots}}{\text{Pole} \times \text{Phase}}$$



Distributed

$$\beta = \frac{180^\circ \times \text{Poles}}{\text{slots}}$$

$$\text{Distribution factor, } K_d = \frac{\sin\frac{m\beta}{2}}{m\sin\frac{\beta}{2}}$$

Concentric winding → $[K_d = 1]$

Distributed winding → $[K_d < 1]$

(1) Harmonics are reduced
(2) Induced voltage also reduced.

$$\text{Coil per pole} = \frac{\text{Number of Coils}}{\text{Number of Poles}}$$

$$\text{Coil group} = \text{Number of Phase} \times \text{Number of Poles}$$

$$\text{Coil group per pole per Phase} = \frac{\text{Number of coil group}}{\text{Phase} \times \text{Pole}}$$

$$\text{Electrical degree} = \frac{\text{Number of Pole Pair}}{\text{Number of slot}} \times 360^\circ$$

$$\text{Phase displacement} = \frac{\text{Number of slots} \times 180^\circ}{\text{Number of slots per pole}}$$

1-ϕ Induction Motor Winding :-

Stator → Main Winding / Running Winding
→ Starting Winding / Auxiliary Winding

Running Winding :- → मोटे तार से बनाते हैं,
→ उसे स्लाट के अन्दर वाले हिस्से में करते हैं,
→ पहले स्लाट में Running Winding जाएगी,

Starting Winding :- → पतले तार से बनाते हैं,
→ उसे स्लॉट के बाहर वाले हिस्से में किया जाता है,

→ दोनों वाइंडिंग की पिच अलग-2 हो सकती है,
→ दोनों में क्वाइल की संख्या अलग-2 हो सकती है,

① Balance Test :- इससे ये पता करते हैं कि प्रत्येक फेज में 120° displacement है या नहीं, इसमें armature पर 220V देकर धारा को नापते हैं, यदि धारा समान है तो balance है,

② Continuity Test :- Open Circuit Test :-

Series lamp को Winding के साथ series में जोड़ देते हैं अब यदि बल्ब जलेगा तो ठीक है और यदि bulb नहीं जलता तो Winding open है,

③ Insulation Test :- Megger के एक सिरे को आर्मेचर वाइंडिंग से तथा दूसरे को मशीन की body से जोड़ते हैं, यदि megger अनन्त दिखाता है तो ठीक है और यदि शून्य देगा तो earth fault हुआ है,

④ Short Circuit Test :- Winding के दोनों सिरों पर megger जोड़ते हैं,

∞ → सही
0 → short