Course Name: Design of Electric Motors

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Title: Example Problems of Magnetic Circuits

Greetings to all. In the last lecture, we have discussed the magnetic circuits and its analysis with air gaps and without air gaps. In this lecture, we will see some example problems to solve the magnetic circuits with air gaps. Let us consider the same magnetic circuit what we have discussed in the last lecture and it has a permeability mu and length all those things will be same. Let us consider the length of air gap LG is equals to 1 mm and mu naught is equals to 4 pi into 10 power minus 7 Henry per meter and mu r relative permeability of the core is 3000 and area with respect to the air gap and area with respect to the core cross sectional area is equals to 100 mm square and number of tons is equals to 100 and current flowing through the coil I is equals to 10 amperes. The problem what we have to solve here is find the inductance value and reluctance of core and air gap.

Draw the waveforms B versus H and inductance versus current, flux linkage versus current with respect to the variation of air gap by varying the air gap length how this performance curves will vary. calculate the reluctance. Reluctance is equals to what? LC by mu naught mu r into AC. Here length of the core how much it has given? LG is equals to 1 mm and LC equals to 50 mm.

Consider it is 50 mm, 50 into 10 power minus 3 divided by mu naught and mu r value 3000 is the mu r value and mu naught is 4 pi into 10 power minus 7 into area of cross section of the core is 100 mm square. We will see the reluctance of the core is 1.3 into 10 power 5 1 by Henry and reluctance of the air gap is equals to LG by mu naught into AG. Specific length of the air gap or length of the air gap is equals to 1 mm is given. So, 1 into 10 power minus 3 divided by same numbers 3004 pi into 10 power minus 7.

Air gap cross sectional area also same as the core cross sectional area by neglecting the fringing effect 100 mm square. And we will see the air gap reluctance will be 79.6 into 10 power 5 1 by Henry. From these two numbers, we can see that reluctance of the air gap is dominant as compared to the reluctance of the core because reluctance of the air gap is 79.6 and reluctance of the core is 1.

3 into 10 power 5 ratios are there constants. Reluctance of the air gap is greater than the reluctance of the core. Then effective reluctance we can consider it as a RG only by neglecting the RC. We are neglecting the reluctance of the core and we are considering R equivalent will be 79.6 into 10 power 5, units:1 by Henry.

Now, we will see the inductance value L is equals to n square by effective reluctance. n square is nothing but n number of tons with respect to the coil is 100. 100 square divided by reluctance effective reluctance is 79.6 into 10 power 5. Then inductance we will get it 1.25 milli Henry. Now, we will see the variation of LG how it is affecting the reluctance inductance and flux. The relation with respect to the air gap length, the reluctance is equals to what L by mu A and inductance n square by reluctance and flux is nothing but mmf by reluctance. So, how these parameters reluctance inductance and flux magnitudes will vary by changing the air gap length we will see now. If we will increase the air gap length reluctance what it will happen reluctance also will increase inductance will come down and flux also will come down because of the inversely proportional relation.

If we will increase or if we will decrease the length of air gap already we have seen the increasing the air gap length. So, reluctance will come down and inductance will increase and flux also will increase. Similarly, if we will increase the air gap cross sectional area Ag is increased means what it will happen to the reluctance reluctance will come down and inductance will increase and flux also will increase. If we will decrease the air gap cross sectional area the reluctance will increase inductance value will decrease because the reluctance and inductance are in a inversely relation and flux is also decreasing because the reluctance is increased. The variation with respect to the air gap length we have seen.

Now, we will see the performance curves how BH curves will vary and then inductance versus current flux linkage versus current by changing the air gap. For a some value of air gap length it will be like this. If we are increasing the air gap length the reluctance is increasing flux also decreasing flux is decreasing means B values also will come down. So, it will come in this fashion if air gap length is higher then we will see some linear characteristics like this fashion the length of air gap is increasing and flux linkages versus current if we will see that curves also in a same fashion similar to the BH curves. Here also the length of air gap is increasing in this fashion.

The inductance versus current waveforms we can see for a given value of air gap the inductance versus current waveforms will be in this fashion. If we will change the air gap it will vary in this fashion by increasing air gap length. These are the performance curves with respect to the air gap length variation. We will see one more example by considering the different cross sectional areas or different lengths of magnetic paths. Let us consider a magnetic circuit in this fashion.

Excited electrical coil is this side having a flow variable I and effort variable V and number of turns N and then dimensions of the core in this portion is 2 here 4 similarly this side also 4, 2 and window height and width both are 10 mm and depth if we will see the depth this also 4 here and here 2, 10, 2 and given number of turns N is equals to 100 current I is equals to 10 and core permeability mu R is equals to 5000 all numbers are in mm all dimensions given in this magnetic circuits are in mm. Now, we have to find the flux densities at the point x let us consider the two points this is y and this point is x because these two cross sectional areas are different, but flux in the core is same. So, we have to find the flux densities at the point x and y and draw the equivalent circuit. This is problem 1 and this is problem 2. So, to find the B fields at different points we should know the area flux density is nothing, but phi by A, flux per unit area.

So, first we will calculate the areas ax and ay the cross sectional area with respect to the x portion is nothing, but width and into depth. So, width is nothing, but what 4 mm and in depth is 4 mm again. So, we will see 16 mm square similarly ay is nothing, but 4 into 2 then 8 mm square we will see here ax is greater than ay. That means, Bx should be less than By this is conclusion 1. The chances of possible maximum flux density is y region only as compared to the x region the chances for maximum flux density is in this region.

So, we can say that in this region the maximum flux density will occur. So, B max we can consider it as By. So, from B max flux density at point y is equals to 1.25 tesla flux density at x value or x point we have to calculate at point x flux is same in the core. That means, Bx into Ax is equals to flux density at the point y and ay with respect to that particular cross sectional area.

So, Bx is equals to By into ay area of cross section with respect to the y point or region and area of cross section with respect to the x region. If we will substitute everything the area with respect to the x region is 16 mm square and area with respect to y region is 8 mm square mm square mm square will be cancelled each other this is 1.25 tesla. So, finally, we will see 0.625 tesla in Bx region. The next question what it is asked in the problem is equivalent circuit. The equivalent circuit the source will be mmf or effort variable is mmf and flow variable is what d phi by dt. Flow and effort variables are defined with respect to the gyrator principles. Next we have to draw the capacitors magnetic capacitances. So, with respect to the I will copy this image for easy understanding.

Here if we will see the cross sectional area with respect to the y region is different the cross sectional area is in the x region is different. So, the magnetic path lengths are different in all these regions. So, first I will start with starting x region there will be a some capacitance with respect to this x region this side, this region and this side also x region is there. So, that capacitance will be Cm x. Next, another capacitance is there at the x region.

In y region we have the Cm y and Cm y this side. So, after adding this all these capacitors in series we will get the equivalent circuit. This is Cm x and flow variable is d phi by dt. This is the equivalent circuit for a given different cross sectional area. Here Cm x is equals to 1 by reluctance we can write it mu naught mu r into a divided by L.

So, length with respect to the x portion length area of cross section with respect to the x portion we know and permeability also we know then we can calculate the Cm x even though it does not ask in the question we can calculate the reluctance values or magnetic capacitance. Next in order to solve any type of magnetic circuit let us consider the magnetic circuit with different air gaps and different structure what we have discussed as of now. The coil is placed on the middle limb, current is I and number of turns n and voltage is V. In order to draw the equivalent circuit we have to mark the locations with respect to the different parts of the iron and different parts of the air gaps. Let us say this is point 1, this is point 2, point 3, point 4, 5, this is at point 6, point 7, this is at air gap is 8 and this is 9.

So, we have to mark the locations with different magnetic lengths or different flux densities are existing in the circuit and the approach will be same for this problem also. We can follow the same procedural steps what we have discussed for the magnetic circuits. I will draw only magnetic equivalent circuit for this problem and then remaining analysis we can do it. Next MMF we have to draw that is the effort variable and then capacitance with respect to the region 1 is CM1 and then region 2 capacitance is CM2, region 3 capacitance is CM3, region 4 capacitance CM4. This side we have capacitance with respect to the region 5, capacitance with respect to the region 6 and then 7, 8 and 9.

So, for a given circuit how to draw the equivalent circuit is nothing but this is the solution. With this I am concluding this lecture. In this lecture we have discussed the problems with respect to the magnetic circuits and the solutions also we have discussed and how to draw the magnetic equivalent circuits by utilizing the gyrator capacitor models also we have discussed. Thank you.