Course Name: Design of Electric Motors

Professor Name: Dr. Prathap Reddy B

Department Name: Electronic Systems Engineering

Institute Name: Indian Institute of Science Bengaluru

Week: 07

Lecture: 35

Title: Design Procedure of an Electric Machine

Greetings to all, in the last lecture we have discussed the sizing equations with respect to the volume product and D cube l equations and D power 2.5 l equations we have discussed. In this lecture we will discuss the generalized procedure for designing a any type of electrical machines like what are the steps we have to follow for designing the electrical machines. So, in this step, step 1, we have to define the basic requirements or specifications. As per the specifications only we have to start the design procedure. First we have to define the basic requirements and specific or specifications.

Then we have to decide the what is the type of a machine, which type of a machine we are going to design it, whether it is induction machine or synchronous machine or DC machine or BLDC. So, which type of motor we are designing? Next which type of construction like a internal interior rotor or exterior rotor, which type of rotor we are constructing? We can see here this is one example for inner rotor, this is the stator and this is the inner rotor. This machine is a induction machine, where inner rotor and outer stator and rotor is a type of squirrel cage. So, we have to decide which type of machine we are going to design.

So, let us say induction machine we are designing, then squirrel cage or slip ring induction motor, which one? First we have to decide that thing at the first step. After that we have to see and we have to follow certain type of standards. Then initial specifications, initial specs like efficiency, torque or with respect to peak torque, breakdown torque and rated one and torque at the blocked rotor condition and speeds. Different requirements we have to note it down that is the step 1. Next step is step 2.

In step 2, we have to find the main dimensions of the machine. Main dimensions of a machines we have to decide that is inner diameter of the stator, outer diameter of the stator and core length etcetera. For calculating main dimensions, we have to select the magnetic loading values and electric loading values precisely. These are the two terms

related to the electric loading and this is the term with respect to the magnetic loading. We have to select as per the material how up to what limit it is feasible like 1 to 2 Tesla.

If you are selecting for certain kind of material for iron, we can consider up to 1.5 Tesla to 1.8 Tesla for steel what is the maximum possible flux density. Similarly for different type of materials, what is the maximum possible flux densities? Which type of steels we are utilizing it and what is the maximum flux densities and then BH curves. We have to analyze everything and then we have to select the magnetic loading without any saturation.

Then electric loading values and current density values we have to select and based on that calculate the main dimensions. Once the main dimensions are done that means, we know the stator inner diameter. We can see here we know the stator inner diameter and stator outer diameter and how much length of a machine we know it now. The next point is we have to design this stator core like what type of winding is there or what type of winding is required and how many number of turns and how to select the laminations and what is the size or area of the stator slot and how much back iron we should keep it width and how much teeth width we have to keep all those things we have to calculate it that is with respect to the stator core design. Where slot geometry, type of winding and number of turns per phase and then area of the slot and materials already considered, but for making the windings and core laminations and what is the lamination thickness and number of slots all these things we have to say design with respect to the step 3.

Next case step 4, next step we have to see rotor design. Now, we have done the stator right here. After doing the stator design, now we have to do the rotor design. In the rotor design, we have finalized which type of rotor we are utilizing it. For example, squirrel cage rotor, how many bars we should consider and what is the skewing angle and what about the end rings of the rotor and then what is the shaft diameter like for example, for handling the high torques the shaft diameter may be different for handling the higher speeds at lower torques the diameter will be different like inertia will be different and depends upon the application we have to design the rotor.

In rotor design, we have to see the rotor geometry and torque or speed requirements. Based on that we have to design the rotor and then type of winding and then materials and laminations, number of slots and then one more thing is bearing requirements. What type of bearings we have to utilize it to make the design? For example, for higher speed different type of bearing arrangement required for higher torque different type of bearing arrangement. So, based on that we have to design the rotor structure. After this thing, we have to analyze the machine parameters in step 5.

In the step 4, for example, permanent magnet rotor is there. What kind of magnetic material we have to utilize it? There is no winding. Then what is the BH curve

properties and then how to handle the required torque and speed, what is the magnet volume and everything we have to calculate it accordingly. Whether it may be induction machine, synchronous machine or BLDC, permanent magnet machines, any machine the same steps we have to follow to get the design of that particular machine. The next machine parameters with respect to the equivalent circuit model, equivalent circuit parameters, then losses and then torque values like what is the peak torque, what is the blocked rotor torque and then what is the rated torque.

Different type of torque we have to calculate it and efficiency and then different inductances and different inductance values, leakage, mutual, magnetizing all those inductance values and resistance values we have to calculate it. Then the step 5, in step 6, we have to determine or we have to verify the saturation limits to meet the required torque rating, torque or power rating. After doing the analysis up to step 5, we have to verify whether the core may saturate or not, we have to verify it and then for a given torque rating or for a given current, we can validate that thing. After that thing, once the validation is done with respect to the given torque and power ratings, this is nothing but I can say validation step. If the requirements we are meeting, then no need to do the iterative procedure, otherwise we have to do the iterative procedure from step 2 till to reach the given specifications.

Then we have to go back to the step 2 and step 3, 4, 5, 6, 7, we have to do it. After this thing, we have to check the standards for final design like IEC standards and IEEE standards and NEMA standards, we have discussed in the design of electrical machines lectures. Based on these standards, we have to make the final design. This is step 8. The next thermal design we have to see based upon the final design, whether what is the temperature rise with respect to the losses and depends upon the rotational speeds and torques.

Any temperature rise is there or not, we have to verify it and appropriately we have to design the thermal design, thermal system. If requires, we can push this step as above step 8 and then, validation with respect to the standards, we can make it as step 9. First, we will do the thermal design, then make the final design with respect to the standards. At the end, we have to verify the figure of merits. Step 10, figure of merits is nothing but with respect to the magnetic shear stress that is sigma m and then, torque to weight ratio and then, power to weight ratio.

After designing the machine, we have to compare with respect to the other machines. There, we have to see the figure of merits or comparison parameters, torque to weight ratios and power to weight ratios and magnetic shear stress. Also, we can see the efficiencies for a given power rating. These are the design steps or design procedure we have to follow for designing of an electrical machine whether it can be induction

machine or a synchronous machine or permanent magnet machine or any type of machine. These are the basic steps.

With this, I am concluding this lecture. In the next lecture, we will see the induction machine design. As of now, we have discussed the generalized principles for a design of an electrical machine with respect to the sizing equations like main dimensions and standards and then, procedure we have discussed. Thank you.