The University Of Sheffield.

Electronic & Electrical Engineering.

EEE305 MACHINE DESIGN

Credits: 10

Course Description including Aims

The aims are:

1. To develop an understanding of the relationship between dimensions and rating of machines.
2. To introduce the principles of winding designs.
3. To develop techniques for the design of permanent magnet machines.
4. To calculate representative winding reactances.

Outline Syllabus

Machine Ratings : leading dimension of machines, electric and magnetic loadings, thermal design considerations. **Windings :** types of windings, their design, choice of winding arrangements, harmonic effects. winding reactances. **Permanent Magnets :** types of magnet, analysis and design of PM devices, design of permanent magnet machines.

Time Allocation

24 lectures plus 12 hours of additional support material.

Recommended Previous Courses

EEE223 'Electrical energy management and conversion'.

Assessment

2 Hour examination, answer 3 questions from 4.

Recommended Books

Say, M.G.	*Alternating Current Machines*	(McGraw-Hill)
Miller, T.J.E.	*Brushless Permanent-Magnet and Reluctance Motor Drives*	(Oxford Science)
Hendershot, J.R.& Miller, T.J.E.	*Design of Brushless Permanent Magnet Motors*	(Oxford Science)
Kenjo, T.	*Permanent Magnet and Brushless DC Motors*	(Oxford Science)
Lipo, T.A.	*Introduction to AC machine design*	(Univ of Wisconsin)

Objectives

On completion of the module successful students will be able to

1. Calculate the leading dimensions of a machine subject to the specified design constraints.
2. Develop winding layouts and calculate the harmonic content of their mmf or of the emf induced in the windings by a rotating field.
3. Suggest the choice of an appropriate permanent magnet material and its main dimensions when used in an electric machine.
4. Develop the skill for magnetic circuit analysis of permanent magnet machines, including working point, airgap flux density, maximum energy product, demagnetisation withstand and temperature effect.
5. Calculate the reactance of a winding or components of the reactance from the dimensions of a machine and relate these to equivalent circuit models developed in earlier years of the course.

Detailed Syllabus

1. Outline of course contents, rationale of the course, an overview of machine specification and limiting technologies, examples of computer-aided-design.
2. Development of the general output equation relating dimensions to output torque and electric and magnetic loadings.
3. Discussion of the limiting material properties and operational conditions on the output power.
4. Application of the output equation to specific motor topologies, design objectives and motor types.

5-6 Development of the general emf equation for an ac winding taking account of coil span, winding distribution and skew. Calculation of harmonic winding factors.

7. Induced emf due to a non-sinusoidal rotating field. Harmonic content of practical windings.
8. Resultant space and time harmonic fields for single and three-phase windings.

9-10. Three phase winding layouts, winding phase vectors, winding factors.

11. Permanent magnets, typical B/H characteristics, important properties, nomenclature and definition.
12. Equivalent circuit models, working points, graphical interpretation and critical design objectives.
13. Analytical models of magnet behaviour, calculation of open circuit flux density and demagnetisation conditions. Magnet recoil operation.
14. Calculation of magnet dimensions for specific operational conditions, minimum magnet volume conditions.

15-16. Application of magnets in permanent-magnet machines and machine topologies.

17. Review of equivalent circuit models for dc and ac machines.
18. Calculation of air-gap fields and winding reactance for concentrated and distributed windings. Relationship to main magnetic circuit dimensions.

19-20. Calculation of magnetising reactance and major components of leakage reactance in machines.

UK-SPEC/IET Learning Outcomes

Outcome Code	Supporting Statement
SM1p	The theories of electromagnetics, energy conversion, magnetic circuit, properties of materials and loss mechanism are uniquely combined in this module, with close relation to engineering application, such as the influence, analysis and minimisation techniques of harmonics in both magnetomotive force (mmf), electromotive force (emf), and winding inductances are comprehensively discussed, together with their relation to electrical machine designs. The students will be able to demonstrate the ability to design modern electrical machines and their knowledge will be tested in the examination.
SM1m	Students will be able to understand and analyse the phenomena of parasitic effects such as cogging torque and leakage flux, etc. in electrical machines in order to reach a good design for different engineering applications.
SM2p/SM2m	The application of mathematical tools to engineering problems, from field harmonic analysis, magnetic circuit analysis, to derive the relationship between machine size and design parameters, is a fundamental aspect of electrical machine design. This is tested in the examination.
SM3p/SM3m	The machine design is multi-disciplinary, including electromagnetics, mechanics, thermal management, computer-aided design. These are fully integrated in the course and tested in the examination.
SM4m	The application of various electrical machines to different market sectors, ranging from domestic appliances, wind power generators, to electric vehicles, is emphasized, and special considerations of machine design in order to suit for a specific application are fully aware of.
SM5m	Linear analytical models are employed throughout the course, but their limitations due to material nonlinearity lead to the necessity of numerical analysis such as finite element analysis or approximation in the analysis. Such skills are key techniques for machine design. Tested in examination.
SM6m	Skilfully applying the multi-disciplinary knowledge is a key to good machine design. This is particularly emphasized in the course.
EA1p	The essence of this module is to apply basic knowledge, including electromagnetics, energy conversion, magnetic circuit, properties of materials and loss mechanism, to derive the relationship between dimensions and output torque and power, to analysis the harmonic effect, losses and demagnetisation withstand etc. It is tested in the examination.
EA1m	The basics relating to electromagnetics, mechanics and thermal management have been comprehensively introduced. Students are expected to use those taught basics to analyse the performance of electrical machines for specific industrial applications. This will be tested in the examination.
EA2p	Analytical analysis and modelling techniques are required throughout this module and subsequently used in the performance analysis. This is tested in the examination.
EA2m	Different analytical methods relating to the calculation of EMF, output torque, iron losses and winding inductances are introduced throughout this module. Students will master those skills and be able to analyse the performance of a designed machine. This will be tested in the examination.
EA3p	Due to non-linear phenomena in the magnetic circuit and harmonic effect, numerical method is often required, while the complexity of the subject requires necessary approximation.

EA3m	Various numerical methods and practical engineering techniques are taught in the module, together with their merits and demerits.
EA5m	The students are required to demonstrate the ability of analysing the new machine topologies.
D1p / D1m	For different application, the emphasis of machine design may be on the cost, reliability, torque/power density, or other performance according to the customers, which will lead to different machine designs, as shown by examples in the module. Students are taught to use assumptions due to the complex nature of machine design, and they are aware of different assumption might lead to different final design of electrical machines. Apart from analytical modelling, students are taught that the sophisticated numerical modelling could effectively mitigate the inaccuracy introduced due to assumption in analytical modelling.
D2p /D2m	Electrical machines are always required to be designed to suit for a specific application with special constraints. This is tested in the examination. The theories relating to electromagnetics are comprehensively introduced throughout this module, students will be able to use those theories to analyse the performance of new machine topologies. This will be tested in the examination.
D3p / D3m	Students are taught to use assumptions due to the complex nature of machine design, and they are aware of different assumption might lead to different final design of electrical machines. Apart from analytical modelling, students are taught that the sophisticated numerical modelling could effectively mitigate the inaccuracy introduced due to assumption in analytical modelling.
D5i	The students are aware of the fact that the machine design is mainly about the balance between the cost and performance. This has been emphasized throughout the module.
EP1p / EP1m	Students are taught that any development in new materials, such as rare-earth magnets, superconductors, new insulation materials, or modelling techniques will be reflected in the machine design.
EP2p / EP2m	Students are taught the characteristics of various soft and hard materials (e.g. copper, iron laminations and permanent magnets), loss mechanism, property variations according to different operating environments and cost implications. Such skill is tested in the examination.
EP6p, **EP6m**	The students are taught to be aware of test and industrial standards**.**
EP9m	Students are taught the techniques how to utilise the advantages and overcome the disadvantages of various soft and hard materials, as well as new emerging materials, in developing new machine topologies and improve the machine performance.
EP10m	The module emphasizes that the machine always needs to be designed under cost and environment constraints for domestic, vehicle and aerospace applications. Students are taught how to consider these into the practical design, as tested in the examination.
ET2fl	The students are aware of the fact that the cost and environmental impact of different materials will have a significant impact on their machine design.
ET4fl	The students are aware of the fact that the cost and environmental impact of different materials will have a significant impact on their machine design.
ET5fl	The students are taught to be aware of the test and industrial standards.