SCOPE OF THE THESIS

Extensive investigations have been carried out in the past two decades on the electromagnetic and electro mechanical effects in solid iron subjected to alternating and rotating magnetic fields[1,6,9,15,17,20,22,23,28,29,30,31,34]. The results of these investigations can be directly applied to study the behaviour of induction machines with solid mild steel rotors.

This thesis is based on a study of the behaviour of one form of modification of the solid iron rotors, namely, the rotors having axial grooves milled in the form of narrow slits. Gibbs[15] was the first to suggest that such a modification would improve the performance of a smooth solid rotor machine. This has subsequently been observed experimentally by Gopal[16] and Sharali & Adkins[4]. Chalmers[10] has given a set of experimental results on the asynchronous operation of turbo-alternator (which is basically a slotted solid rotor structure) and has presented an analysis assuming the rotor surface to be smooth. Kesavamurthy and Rajagopalan[26] have suggested that the observed discrepancy between the theoretical and experimental results of Chalmers[10] is due to the fact that the analysis ignores the effect of slotting.

The main aim of the present investigation is to develop an analysis to predict the performance of slitted rotor machine and bring out clearly the influence of all the parameters that affect its behaviour. With this object in view an original approach based on the novel concept that the slitted surface of the rotor is a flux line has been presented. Based on this concept, three

methods of analysis have been developed which take into account all the factors affecting the behaviour of these machines and in addition the effect of the saturation of the rotor material.

In order to substantiate the results of the theoretical analysis developed, experimental investigations have been carried out on two machines with the following combinations of the number and depth of the slits for their rotors:

1. Machine - I (3 h.p. frame)
   (a) Unslotted rotor (smooth cylindrical rotor)
   (b) 6 slits: (i) 1/4" depth; (ii) 1/2" depth.
   (c) 12 slits: (i) 1/4" depth; (ii) 1/2" depth; (iii) round slots of 1/4" dia., lip height 1/8" and Lip width 1/16".
   (d) 24 slits: 1 cm depth.
   (e) 38 slits: (i) 0.5 cm depth; (ii) 1 cm depth.
2. Machine - II (1 h.p. frame)
   (a) Unslotted rotor (smooth cylindrical rotor)
   (b) 32 slits: (i) 0.788 cm depth ; (ii) 1 cm. depth.

Each of these rotors have been tested with two different types of end terminations (i) with thick copper end rings and (ii) with no end rings. Five of the rotors under Machine - I and one rotor of Machine - II have also been tested with an additional cage (with copper strips) incorporated in the slits. The results of the experimental investigation confirm all the ideas provided by the analysis as regards the influence of the parameters

affecting the behaviour of these machines.

The development of the thesis which is in three parts is as follows:

In Part - I of the thesis a one-dimensional model for the slitted rotor has been developed. In order to bring the problem under the scope of an analytical study the concept that the slitted surface is a flux line has been invoked. Such a concept is physically plausible and is in conformity with the generally accepted concept that the surface of a smooth solid rotor is a flux line[20]. Based on this concept, the problem is further simplified by assuming a certain geometry for the flux contours and the basic equations governing the field distribution inside the iron have been formulated.

In Part - II of the thesis, it is shown that the concept of a unit conductor ('T' shaped conductor of width unity for the top region of thickness d and width $1/\tau$ for the bottom region extending to infinity) is a convenient form for the study of the behaviour of slitted rotor machines and three methods of analysis have been presented leading to the evaluation of the impedance and hence the behaviour of this unit conductor.

(i) Method - I: On the assumption of a constant permeability for each of the regions of the unit conductor a linear theory has been developed which is capable of extension to take saturation of the magnetic material into account.

(ii) Method - II: A step-by-step graphical/numerical method[34] available for certain problems involving saturation has been extended to the present problem of the study of the behaviour of the unit conductor. The main interesting feature of this extension is the complete normalization of the graphical construction, ultimately, leading to analytical expressions for the behaviour of the unit conductor.

(iii) Method - III: An alternative approach to take saturation into account, based on the limiting non-linear theory employed elsewhere by McConnell,[29,30] Agarwal[1] and several other authors[4,10, 31] has been shown to be applicable for the unit conductor as well. This method, also leads to analytical expressions for the behaviour of unit conductor

The common feature of these methods of analysis is the choice of two (dimensionless) parameters leading to a set of non-dimensionalized curves in each method capable of direct and easy application for any unit conductor and under different operating conditions. The three methods of analysis have been compared amongst themselves over a wide range of the dimensionless parameters and the agreement in the impedance of the unit conductor evaluated by these methods is found to be good.

In Part - III of the thesis, three important applications of the methods of analysis developed for the unit conductor have been dealt with.

(i) Slitted Rotor Induction Machines

Performance equations have been presented based on the above methods of analysis and the predetermined performance is shown to be in good agreement with the test results. From a study of the experimental results it is shown that the performance depends upon (i) the number of slits; (ii) depth and width of the slits; (iii) saturation of the magnetic material and (iv) the nature of end terminations. It is further established that the performance in general, improves with the number and depth of the slits and that there exists an optimum depth to realize the best performance for any given number and width of the slits.

(ii) Asynchronous Operation of Turbo-alternators:

The analysis developed for the unit conductor has been extended to predetermine the behaviour of turbo-alternators under asynchronous operating conditions. The interesting feature of this extension is the development of an equivalent circuit for the rotor. Based on this analysis the behaviour of a 60 MW turbo-alternator has been predetermined and is found to be in good agreement with the test results of Chalmers[10].

(iii) Slitted rotor machine with an additional cage incorporated in the slits:

A general method of analysis has been developed for this case as well leading to the development of an equivalent circuit for the machine. The theoretical results obtained by this analysis are found to be in good agreement with the test results.

Lastly, the thesis takes up the analysis of a slitted rotor machine from an entirely different approach, that is, based on the concept of a composite permeability for the slitted region. This approach has been employed by several authors[12,32,42,43] for the study of the behaviour of conventional machines like a squirrel cage induction motor. Such an approach, which suggests itself at first sight to be a reasonable one for the present problem as well, is shown to be inadequate to account for all the factors that influence the performance of a slitted rotor machine and yields erroneous results.