SYNOPSIS

The polyphase induction machine with solid iron rotor has been the subject of numerous investigations . The performance of this machine is characterised by the electromagnetic torque resulting from the rotor eddy currents reacting with the inducing air-gap field. These eddy currents have a distribution and a definite depth of penetration beyond which the rotor field quantities become negligibly small. The small depth of field penetration in solid rotors has been recognised to cause a high rotor impedance resulting in large slips and rotor heating. It is, therefore, of interest to examine whether the penetration of the field in the rotor can be increased in order to reduce its impedance. A method of accomplishing this is to cut thin uniformly spaced axial slits on the rotor surface. When this is done, there is a considerable change in the performance of the rotor and thus forms the subject of the present investigations. Apart from the steady state performance of induction machines, these investigations have the further significance that they can be applied to the study of the starting and asynchronous performance of turbo-alternators.

The scope of this thesis is, therefore, to examine the behaviour of induction machine with solid and slitted rotors, and with and without non-magnetic conductors in the

slits when run as induction motor and as d.c. brake. For each case, both types of rotor terminations i.e. with and without copper endrings are considered.

The development of the subject matter which is presented in six Chapters is on the following lines :-

(1) The field distribution inside the rotor is governed by Maxwell's field equations and the electric and magnetic properties of the rotor. It is obvious that a successful comparison between theory and experiment will involve an experimental investigation to cover a wide range of rotors wherein the depth, width and the number of slits are varied. Previous work[13,35] in this direction is incomplete and in this thesis, an attempt is made to report the results of such an experimental investigation carried out on more than 50 cases of rotors run as induction motor and also as d.c. brake. The results bring out their characteristic differences and in addition, the effect of end terminations and also the influence of axial copper conductors in the slits.

The reasons for the variation of rotor impedance and power factor obtained from load tests are further investigated by a study of the flux attenuation in the slitted region of the rotor. Such a measurement of flux penetration over a range of frequencies is considered in detail in this chapter and it is shown that this flux attenuation by itself can offer a qualitative explanation for their variations and hence the rotor performance. Besides, a new method of measuring slip in the low slip region for induction motor operation also forms a special feature of this chapter.

(2) For the study of slitted rotors, the existing linear theory[5,13,28] for solid rotors has to be modified to take into account the differences in their electric and magnetic properties in different directions. This is attempted. Furthermore, the theory has also to take into account satisfactorily the effect of the rotor terminating rings and axial copper conductors in the slits. This has also been studied. Computations have been made on the basis of linear theory and the results are compared with test values for different cases. Two methods of approach for pre-determination of performance based on (i) permeability corresponding to a surface magnetisation and (ii) permeability assumed constant for the entire range of operation, have been adopted and it is shown that the pre-determination by either method does not lead to satisfactory predictions.

(3) To account for rotor saturation, an attempt is

made to evolve a generalised non-linear approach. For this, the linear theory presented in the previous chapter is extended for application in the non-linear region. This results in a new treatment and the analysis of different types of slitted rotors and the non-linearities associated with them are shown to be only special cases of this general non-linear approach. Consequently, the scope of this treatment covers wide slitted rotors in addition to the narrow-slitted ones. The former case arises when the ratio of the width of slits to the total peripheral width of the rotor exceeds 30%, when a definite initial magnetising current is required to drive flux (corresponding to the rated stator voltage as induction motor) through the rotor.

The non-linear theory is then applied to a large number of rotors, narrow-slitted and wide - slitted and with and without axial copper conductors in slits and also for the cases of the two types of rotor end terminations. The slit widths are varied as 13%, 16%, 33% and 66% of the periphery while the depths are varied as 1/4 inch, 1/2 inch, 3/4 inch and 1¼ inches. The number of slits was kept as 47, 23 and 12 respectively. Computations thus made for a wide range of slips for operation as induction motor and also as d.c. brake, are compared with test results. It is shown that the non-linear theory gives predictions which are in better conformity with experimental results.

(4) In the treatment of slitted rotors, two special cases arise (a) a rotor fabricated with deep, wedge shaped ferromagnetic bars separated from each other by non-magnetic material which may be a conductor or an insulating material (b) a rotor in which the slitted medium comprises of a thin hollow copper cylinder shrunk tightly on to a solid ferromagnetic cylinder. Investigations carried out for these two cases form the subject matter of this chapter.

(5) The analysis presented in chapters 2 to 4 are based on assumed field distributions and verified on the basis of overall agreement with experimental results. In addition to the flux penetration studies described in Chapter 1, a study of the surface current density/electric intensity distribution and their possible modes of attenuation is also of fundamental importance and this is attempted in this chapter. Enough experimental evidence is presented to lead to the conclusion that there is a further need to re-examine the problem of slitted rotors to obtain an insight into the secondary phenomena observed.

(6) It is obvious from chapters 2 and 3 that the prediction of performance of slitted rotors is based on a

trial and error process of computation involving labour and tedium. These reiterative processes are complicated by the non-linear nature of the magnetisation characteristics of the rotor in the case of induction motor. Calculations become even more laborious for the rotor run as a d.c. brake since in this case, the non-linearity of the stator and airgap magnetisation characteristics is also to be considered in addition. This chapter , therefore develops computer programmes for the problem of slitted rotors. These are illustrated by flow diagrams. The corresponding Fortran programmes are also included.