CHAPTER 1

INTRODUCTION AND SCOPE OF THE THESIS

The induction motor with solid iron rotor has been the subject of several investigators in the past few decades who offered different methods of analysis to predict its performance, (References 7,9,13,18-30). Among them the works of Pohl, McConnell, Kesavamurthy and Rajagopalan, Angst, Heller, Yee are very significant in that the mechanism of flux penetration, the concept of rotor power factor, accounting of non-linearity and saturation of iron and the effect of finite length were very clearly brought out. These machines have excellent starting properties but poor running characteristics, with low power factor and large slip under full load conditions. This is attributed to the high resistance property of the magnetic steel material. Unlike that of the conventional machine, the solid rotor forms a homogeneous, isotropic medium into which the flux penetrates to induce torque producing currents.

The attention was, then, turned in the direction of improving the performance of these machines by suitable modifications in the rotor. In one such attempt, narrow deep slots, distributed uniformly, were cut on the peripheral surface of the solid rotor and the effect of these slots on the performance of the motor was investigated (References 31,32,33). Rajagopalan and Balarama Murthy(31) observed in their analysis that slotting caused the decrease of rotor impedance due to increased cross sectional area for the flow of eddy currents resulting in better performance as shown in Fig. 1. The torque and the power factor were found to be much higher than those of the solid rotor for all slips, (including the starting condition). Another attempt was made by the same authors(34) to make it still better in its performance by filling the slots with copper. The result was the copper filled slotted rotor closely resembled the double cage or deep bar rotor in respect of speed-torque characteristic. In the concluding part of their investigation, they expressed the opinion that careful design considerations would finally lead to a rotor of this kind to have a flat topped speed-torque characteristic. It is to be noted that both the slitted iron rotor and the copper filled slotted iron rotor are no more homogeneous and can be termed as a sort of composite rotors, having different permeabilities and conductivities in different regions.

The study of the mechanism of flux penetration into the magnetic materials reveals that the flux clings to the surface in a thin layer, called the skin depth, even for low values of slip, and it is in this region where the torque producing currents are significantly present. Therefore, if the conductivity of this region is increased by some means, a marked improvement in the electrical characteristic of such a rotor may be expected. This concept led to the development of another kind of composite rotor which consisted of a basic solid rotor on to which two or three layers of highly conductive and highly magnetic shells or sleeves were placed (References 5,6). A theoretical study made on such a rotor by Wilson, Erdelyi and Hopkins[5] revealed that it was not only the efficiency which increased considerably over that of the solid rotor but also the torque-speed characteristic rose steeply at low slips and remained nearly flat between 20 and 100 percent slips, thus making it resemble a multiple cage rotor, as shown in Figs.2 and 3. Many of the claims were later supported by the experimental study made on induction motor with such rotors by Sarma and Soni[6] and a sample of their results—Output versus slip characteristic -is reproduced here in Fig.4. The composite rotors were constructed by shrunk fitting a highly conductive and then a highly permeable shells on to a basic solid core rotor. However, in the case of a very thin conductive layer rotor, it was obtained by the electro-deposition of the metal. These rotors have inhomogeneity in radial direction due to the various concentric layers having different permeabilities and conductivities.

If the first layer (layer nearest to air gap) is to be a highly permeable one to increase the flux density at the rotor surface it should be relatively thin so as to allow the highly conductive second layer to be nearer the rotor surface, the region of highest current density. Excessive thickness of this conductive layer may increase the reluctance of the magnetic circuit, resulting in the deterioration of speed-torque characteristic. These considerations, perhaps, may demand that the various layers need to be thin to obtain best results, in which case the construction of the composite rotor by shrunk fitting technique may not be possible except by the electro-deposition process. Sarma et al[6] used relatively thick sleeves in their composite rotors designed for low frequencies (60HZ & 110HZ) while Wilson et al[5] used small values for the thicknesses of various layers in their theoretical study of the composite rotors designed for high frequency applications (2000 to 3000HZ). When thin shells are employed, there may be quite a few number of layers to be added to the basic solid core and certainly it will be difficult to develop such a composite rotor either by the method of shrunk fitting or electrolytic process. Therefore, it is worth attempting to find an alternative method of constructing such rotors and then analyse and verify by experiment if such rotors possess the same advantages as those exhibited by the concentric multi-layer rotors. Instead of using multiple number of shells, the composite rotor may be developed by winding toroidally two sheets (one magnetic and the other conductive) of appropriate thicknesses interleaving one with the other. The construction is similar to that used in making toroidal cores of current transformers. Such a structure when used as a rotor may have its own peculiarities such as progressively diminishing pole pitches, the likelihood of peripheral currents near the end region of each layer returning through the next layer etc. But these effects can be considered to be secondary.

In this thesis, an attempt is made to analyse and predict the performance of such rotors. To verify the theoretical results five laboratory models of toroidally wound rotors are developed and constructed and experimental investigation is carried out to obtain their performance characteristics. The whole problem is approached on the following lines. Two kinds of magnetic materials are chosen which differ considerably in magnetic and electrical characteristics-comparatively low resistive mild steel sheet and magnetically superior but electrically inferior transformer lamination sheet. Plain toroidally wound structures of these materials form two typical cases to explore their torque producing capabilities when used as rotors of an induction motor. Then the influence of introducing conductive layers into each of the above rotors on their performance characteristics is studied by constructing composite rotors. Copper and aluminium are used as conductive layers. Experiments are also done at different frequencies to determine the distribution of field quantities in various rotors.

The development of the thesis, Chapter-wise, is as follows:

In Chapter II, the constructional details of the various plain and composite sheet rotors are given in sufficient detail, bringing out all the salient points. A novel winding gear developed in the laboratory to roll the sheets into rotors is described.