Design of Hysteresis Motor

Fig.1 shows a brief flow chart of the design procedure adopted in this work. Considering the winding space available in the motor, the field intensity achievable is expected to be of the order of 100 Oe. The selection of hysteresis material in miniature size motors with input power of less than 10 W and operating magnetic field intensity of 100 Oe is governed by the limitations of the input electric power rather than the volumetric intensity 11. On this basis, the materials that can be selected for operating with magnetic intensity of the order of 100 Oe are "P6 alloy" and "5% Chrome Steel". Laminations of 0.27 mm thickness made out of CRGO 41 sheet are used for the stator stack. As the rotor speed is 6000 rpm, and the standard inverter frequency is 400 Hz, 8 poles are required. So as to reduce the MMF parasitic loss, the winding must be sinusoidally distributed. This will necessitate a large diameter, which will do away with the compactness of the motor. Considering this aspect and also knowing that the MMF parasitic loss is a small portion compared to the flux parasitic loss, in this design winding is not sinusoidally distributed. One coil/pole/phase is selected. In the hysteresis motor, the airgap is decided by the parasitic loss considerations. Flux parasitic loss is due to the undulations of the airgap flux density on account of open slots of the stator. Increasing the airgap can reduce this effect. In the present design, nearly closed slots (24 numbers) are considered with an airgap of 0.15mm. The slot area is considered to accommodate 65 turns of No.35 SWG enameled copper wire. As the acceleration major requirement in this application, so as to get higher starting torque, generally a dual voltage excitation method will be used. A higher voltage will be applied initially and once the motor is started, a reduced voltage will be given for normal running. A six-pulse inverter with the input voltage of 40 V for starting and 24 V for running is used here. The fundamental rms voltages will be 31.2 and 18.7 V respectively during starting and running. A computer program is developed in MATLAB using the equivalent circuit of the hysteresis motor given in literature [2], [3]. The design work out has been analysed for the performance using this program and the design is tuned to get the required performance. The final design data of the motor are: 32.2 V, 18.7 V (run), 3-phase, 400 Hz, 0.17 A (start)/0.102 A (run), 6.2 W (start)/2.3 W (run), 8 pole, 1 coil/pole/phase. The outer diameter Ls 55 mm, inner diameter is 27.8 mm and the axial length of stack is 5 mm.

Test Results and Further Investigations

Comparison of the test results with the computed values is given in Table-I. The measured efficiency of the motor is 60.09% against the calculated value of 63.04%. The difference can be attributed to variations in properties, of the hysteresis material used and also to measurement errors. Low efficiency and low power factor are the major drawbacks of hysteresis motors. An experiment with a purely sinusoidal supply of 31.2 V instead of a six-pulse inverter supply has been conducted and it is seen that the torque developed is more by 9%. Analysis had been carried out and it is observed that with a six-pulse inverter supply, the harmonics of the order of 5, 11, 15, 1/11, 1/5, 5/7, 5/13, etc. act in a reverse direction resulting in the negative torques and also harmonics of the order of 7, 13, 7/11, 1/13, 5/11, 7/13, etc. act in forward direction resulting in positive torques, the net result being a reduction of 7.11% of the torque. Therefore, it is advisable to have a purely sinusoidal supply for the hysteresis motor used in such sensitive applications. Alternatively, a PWM inverter can also be employed with selective harmonic elimination. Effort is made to increase the starting torque so as to get rid of the increased voltage excitation during starting of the motor. It is observed from the analysis by running the developed program for the simulation of this motor that by using a thicker lamination for the stator stack, the starting torque increases. This is because of the fact that with a thicker lamination, the eddy current torque available during starting increases. The eddy current torque is proportional to the square of the thickness of lamination used in the stator stack. This component of the starting torque available at stall goes up by 77% by increasing the lamination thickness 10 0.36 mm instead of the selected 0.27 mm. This enables the motor to start on no load on normal supply of 18.7 V.

References