Optimization of a New Type of Hysteresis Motor Using Genetic Algorithm

M. H. Sadeghi
dept. of power eng., Shahrood Uni. Of Tech.
Shahrood, Iran
mhsadeghi64@gmail.com

A. Darabi
dept. of power eng., Shahrood Uni. Of Tech.
Shahrood, Iran
darabi_ahmad@hotmail.com

Abstract— **HYSTERESIS motors are self-starting synchronous motors that take advantage of the hysteresis characteristics of the magnetic materials. Robust structure, flat speed-torque characteristics, smooth operation and constant low starting current are the outstanding specifications of these machines. Nevertheless, low efficiency and low power factor are among the disadvantages of common hysteresis motors. Very recently, Coreless Dual Discs Hysteresis Motor (CDDHM) has been introduced to enhance the efficiency of the hysteresis motors. So far, design algorithm and impacts of the design parameters on the performance of the CDDHM have not been fully investigated. Conventional optimization algorithms commonly are employed to solve the linear problems and those are not easily applicable for design optimization of a hysteresis machine with a complicated, nonlinear and multi values model. These difficulties are mainly due to the fact that the output torque of a flat hysteresis motor is proportionally related to area of the hysteresis loops on volume of the rotor discs. This paper presents an initial design algorithm and then describes application of a genetic algorithm-based approach with all details solving successfully the maximum efficiency optimization problem of a CDDHM. The output power and efficiency obtained from theory is shown to be in good agreement with the measured values.**

Keywords-component; Coreless Dual Discs Hysteresis Motor; Design; Genetic Algorithm; Optimization.

I. INTRODUCTION

Multi-phase hysteresis motors are special type of brushless and self–starting synchronous motors with flat speed-torque characteristics, smooth operation and low noise level. The rotor is constructed very simply as a robust solid ring or disc of a heat treated alloy steel. Commonly, the starting current is within 1.2 - 1.5 times of the full-load current. On the other hand, low efficiency and low power factor are the most important disadvantages of hysteresis motors [1-2].

Multi-stacks disc type permanent magnet machines are well-known and have been already studied in some papers [3] while two types of the multi stacks flat hysteresis machines named slot-less and core-less dual rotor discs hysteresis motors have been recently introduced and constructed in Shahrood University of Technology, Iran [4-5]. The iron losses of the stator cores of the common hysteresis motors are rather high particularly when employing in the high frequency applications. Therefore a Coreless Dual Discs Hysteresis Motor (CDDHM) potentially can introduce higher efficiency if it is designed properly. Fig. 1 shows the main structure of a CDDHM.

Studying and choosing the optimization algorithms of the electrical machines is so essential due to many variables of design. A proper method should not be time consuming and have ability to find the global extremum of the problem.

In many electrical machines designs optimization, a limit number of variables or constraints have been considered that might achieve weakness results of design. Optimization problems and its difficulties are more important in hysteresis motors because of complicated, nonlinear and multi values model including non-linear cases can be cited, non-linearity of hysteresis delay angle and non-linearity of output torque, because it is proportional to the area of hysteresis loop on the hysteresis ring.

Efficiency enhancement of a CDDHM can be achieved using a proper reliable optimization algorithm involving whole design parameters as variables and input voltages, frequency and output torque as the required characteristics. The Genetic Algorithm is a heuristic optimization method that has good compatibility for this optimization problem as mentioned. Therefore, GA might be use to optimize the efficiency of CDDHM.

Optimum proposed design should be studied and efficiency and power factor of the proposed design should be acceptable and particular.

II. MODELING AND ANALYSIS

To simplify the analysis, two following assumption are made for CDDHM.

a) The motor is working in synchronism and full load condition.

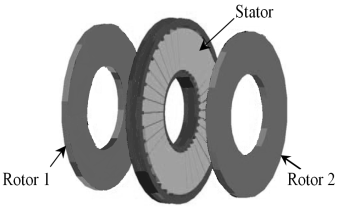

Figure 1. CDDHM structure

b) The stator has sinusoidal distribution poly-phase windings and the stator's magnetic motive force (MMF) is produced by three phase sinusoidal currents.

In this paper we shall get the optimized design by GA using equivalent circuit of CDDHM that has been taken from [4]. Fig.2 shows the equivalent circuit of CDDHM.

III. DESIGN PRINCIPLES

To design a CDDHM, like most other machines, input and output parameters and constraints of design should analyze.

A. Design input parameters

In designing, some of electrical and mechanical input or output of machine could consider as design input parameters. In CDDHM five following parameters have been chosen.

a) P_{out}: output power of motor

b) V_{in}: Input feeding voltage of motor

c) f: feeding frequency

d) n_{syn}: synchronism speed

e) m: phase number

Other design parameters will obtained from input design parameters. Pole number is expressed as follows:

$$p = \frac{120f}{n_{sync}} \tag{1}$$

The output power of the motor is proportional to the area of hysteresis loop in the hysteresis ring. That is, the output power is calculated by (2).

$$P_h = V_h E_h f \tag{2}$$

Where, V_h is the volume of the rotor hysteresis disk, E_h is the area of hysteresis loop in the hysteresis disk and f is the feeding frequency. With choosing normal hysteresis loop, the volume of the rotor hysteresis disk is expressed as follows:

$$V_h = \frac{P_h}{E_h f} \tag{3}$$

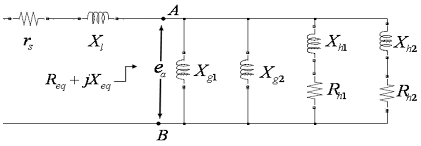

Figure 2. equivalent circuit of CDDHM

B. Design output parameters

Output parameters of design are some mechanical parameters such as the size of different parts of the motor. The most important outputs are as follows:

a) R_i : Inner radius of the rotor disk

b) R_o : Outer radius of the rotor disk

c) N_{ph}: Number of turns per phase

d) $D_{conductor}$: Conductor diameter

e) t_{r1} & t_{r2} : Disk thickness of rotors 1& 2

f) g_1 & g_2 : Air gap length

Chose of inner radius of rotor disk is affected by limit space in inner radius of the rotor disk and stator and winding assumption like end winding. So R_i is obtained as follows:

$$R_i = R_{sh} + l_s + l_f + l_t + l_w \tag{4}$$

Where, R_{sh} is the motor shaft radius, l_s is the thickness of inner ring of stator, l_f is the distance between inner radiuses of the rotor and stator, l_t is distance between motor shaft and winding that is effected by mechanical limits and l_w is allocated space for the end winding which is obtained from follow equation:

$$l_w = \frac{2N_{ph}D^2_{conductor}}{h_w} \tag{5}$$

Where, h_w is allowable height for placing the wires on each other. The maximum efficiency occurs in a certain hysteresis loop. On the other hand, if the thicknesses of two discs are different, each disc will operate on its own hysteresis loop and at least for one of them, the operating loop is not the normal loop. Consequently, the maximum efficiency can be achieved when the thickness of both discs are exactly the same and working on the normal loop. Therefore:

$$t_{r1} = t_{r2} = \frac{V_h}{2\pi(R_o^2 - R_i^2)} \tag{6}$$

Calculating the air gap is so important, so the air gap length is expressed as follows:

$$g_1 = g_2 = \left(\frac{N_l \times D_{conductor} \times K_p}{2}\right) + g_l \tag{7}$$

Where g_l is the distance between the surface of winding and rotor disk and N_l is:

$$N_l = \frac{mN_{ph}D_{conductor}}{\frac{2\pi(R_i - l_s - l_f)}{2} - m_s} \tag{8}$$