

Dc Motor Design and Characteristics Using Matlab

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Abstract:

The basic problem of this paper is building designing steps of direct current (D.C.) motor by using one of MATLAB software facilities called m-file. This will provide testing of motor characteristics and motor performance on model instead original. Program also be used for testing motor performances and for testing motor prototypes because it provides possibility of changing motor dimensions and parameters with acceptable given limit. This is especially desirable for large D.C. motors over 50 kW, because testing of motor for different kinds of load and testing motors dynamic can prevent some malfunctions and damages of motor. More about essential motor dimensions and parameters that are crucial for building a motor steps design will be discussed further in paper. Motor dimensions and parameters calculation in m-file which contains different kinds of core materials will be compared with motor theoretical calculation. This software can also be used to enhance teaching of D.C. motors course.

Keywords: shunt d.c. motors; characteristics; software laboratory ;Matlab/Program(m.file).

تصميم و خصائص محرك التيار المستمر التوازي باستخدام برنامج MATLAB

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الخلاصة :

أن المشكلة الأساسية في هذا البحث تبني خطوات لتصميم محركات من التيار المستمر باستخدام إحدى وسائل برنامج MATLAB لكتابة وتنفيذ البرنامج و يدعى محرر الملف m-. من خلال تنفيذ البرنامج سيزود اختبار الخصائص والأداء للمحرك على النموذج بدلا من ذلك الفعلي. البرنامج يستعمل أيضا لاختبار الأداء للمحرك ولاختبار النماذج المصممة لأنها تزود إمكانية تغيير الأبعاد والعوامل المتغيرة للمحرك بالحد المعطى المقبول. أن هذه الإمكانيات مرغوبة خصوصا للمحركات الكبيرة في تيار مستمر أكثر من 50kW،

كون اختبار المحرك بهذه الطريقة لأحمال مختلفة واختبار ديناميكية المحرك يؤدي لتجنب الإضرار و الأعطال. هذا البحث يناقش التعريف حول الأبعاد والعوامل الضرورية التي تكون حاسمة لبناء خطوات تصميم المحرك وحساب العوامل في محرر الملف-*m* الذي يحتوي الأنواع المختلفة من المواد التي تستخدم كقلب مغناطيسي والتي ستقارن بالحساب النظري للمحرك. هذه البرامج يمكن أيضا أن تستعمل لتحسين تعليم كورس محركات التيار المستمر.

1. Introduction

Computer modeling and simulation tools have been extensively used to support and enhance electric machinery courses. MATLAB with its toolboxes and m-file is one of the most popular software packages used by educators to enhance teaching the process of design and learn characteristics of electric machines [1-2-3-4].

During the last decade, classical and modern control system design methods, involving advanced mathematical techniques and time-consuming calculations have been greatly aided by software packages such as MATLAB/SIMULINK, SPICE, EMTP, SABER, SPECTRE, SIMPLORER, etc., which can provide accurate predictions of the systems behavior in reality [5-6]. In recent years, D.C. motor has become a popular choice in industry applications such as automotive, aerospace consumer, medical, instrumentation. Shunt D.C. motor has advantages over other D.C. motors and induction motors. They have better speed versus torque characteristics, high efficiency, high dynamic response and so on [7]. Electromagnetic and permanent field direct current motor (D.C.) have been widely used in high-performance electrical drives and servo system. There are many difference D.C. motor types in the market and all with it good and bad attributes. Such bad attribute speed and current variables with load. Due to the excellent speed control characteristics of a D.C. motor, it has been widely used in industry (such as cars, trucks and aircraft) even though its maintenance costs are higher than the induction motor. As a result, authors have paid attention to design to get characteristics of D.C. motor and prepared several methods to control speed of such motors. In order to understand this characteristic when we made design and select field and core materials tests must introduce to our selection. Padmakumar S., VivekAgarwal, and Kallol Roy^[8] A tutorial on D.C. motor modeling and simulations in Matlab and implementation of Kalman filter for estimation of states from corrupted or noisy measurement is presented. The author in this paper suggest to be in the first level to learn about design of D.C. motor step by step by using software(m-file) and who far our magnetization curve (flux linkage versus current) will be compatible with our parameters limitation. G.Prasad, N.SreeRamya, P.V.N.Prasad, G.Tulasi Ram Das^[9] The paper presents a model of three phase star connected brushless dc motor considering the behavior of motor during commutation. This process is done in MATLAB/ SIMULINK after development of the brushless (BLDC) motor with sinusoidal and trapezoidal waveforms of back-EMF. Miklosevic, Kresimir ; Spoljaric, Zeljko&Jerkovic, Vedrana^[10] Usage of different kinds of programs, such as Matlab, provides complete static and dynamic state analysis, and testing different kinds of machines by using simulation model instead original. C.Gencer and M.Gendikpinar^[7] introduced modeling of three phase brushless D.C. motor with MATLAB/SIMULINK package program .S.Ayasun

and C. O. Nwanpa in ^[11] they present test of induction motor by using MATLAB/Simulink, while in ^[12] the same researchers presents the open circuit and close circuit tests so that to calculate transformer parameters and its efficiency. K. L. Shi, T. F. Chan, Y. K. Wong, and S. L. Ho^[13], they present modeling and simulation of the three-phase induction motor using Simulink of MATLAB.

The objective of this paper is to execution software programs of D.C. motor design when we selected the ferromagnetic material and supply the calculation essential like rated terminal voltage, rated output in horsepower, armature resistance friction and windage losses and rated speed parameter power to get its essential dimensions and characteristics. More about essential motor parameters that are crucial for building a motor steps design will be discussed further in paper. Motor model in m-file will be compared with motor theoretical calculation which contains different kinds of core materials. These programs include of D.C. shunt motor design method, according to INCE standard^[14]. The software of D.C. motors are integrated into a process of design senior level electric machinery course to enhance teaching of D.C. motors course. The enhancement is achieved by using the software for various educational activities such as classroom demonstration, exercises, and assignments. It has been observed that with the help of simulation results they obtain, students increase their understanding of D.C. motor characteristics and dynamic behavior beyond the understanding they gain from classroom lectures and this paper is organized as following.

2. Matlab/ Design Method

This paper present of basic processes and procedure underling DC motor design. Only simplex lap armature winding are considered. The national Electrical Manufactures Association in NEMA standard MG-1 present guidelines for labeling, classifying, rating, and packaging D.C. motors. A complete list of frame designations and dimensions is available in NEMA standard MG-1. ^[14].The first step to calculate the volume and bore sizing from the rated developed torque for the D.C. motor under the reasonable assumption of 3 percent rotational losses as follow:

$$T_d = k\phi_p l_a = \frac{PZ}{2\pi a} \phi_p l_a \quad (1)$$

Where ϕ_p is the flux per pole, d is the diameter armature, l_a is the armature stack length, p number of poles, a number of parallel path and Z no. of armature conductors.

So if we identify the flux per pole in term of assumed uniform flux density, then multiply by $\frac{\pi d}{\pi d}$ and substitute into (1) and rearrange to yield:

$$T_d = \frac{PZ}{2\pi a} \mathbf{B}_p \frac{k_1 \pi d l_a}{P} I_a \frac{\pi d}{\pi d} \quad (2)$$

Where \mathbf{B}_p flux density under a field pole, k_1 is the ratio of pole arc to pole pitch.

Clearly we can see that the term $\frac{I_a Z}{d\pi a}$ is a surface current density. The value of current density and flux density are maintained at the limits allowable by ability to cool the armature conductors and by saturation limits imposed by ferromagnetic material. So from **equation (2)** we can conclude that:

$$\frac{d^2 l_a}{T_d} = \text{constant}$$

The next step in the initial sizing process of D.C. machine design is to set the outside frame diameter from NEMA frame dimensions. So from this begging calculation we can continue to calculate the essential and important dimensions for all parts of our machine without illustration equations details, except the acceptable limits for some dimensions as follow:

2.1- Armature Design:

The logic flowchart shown below **Figure.(1)** set up the iterative procedure to be followed for the armature design process when we supply its desired rated output power, rated speed and calculate, no. of conductors and then armature resistance to get essential dimensions for armature .^[15-14]

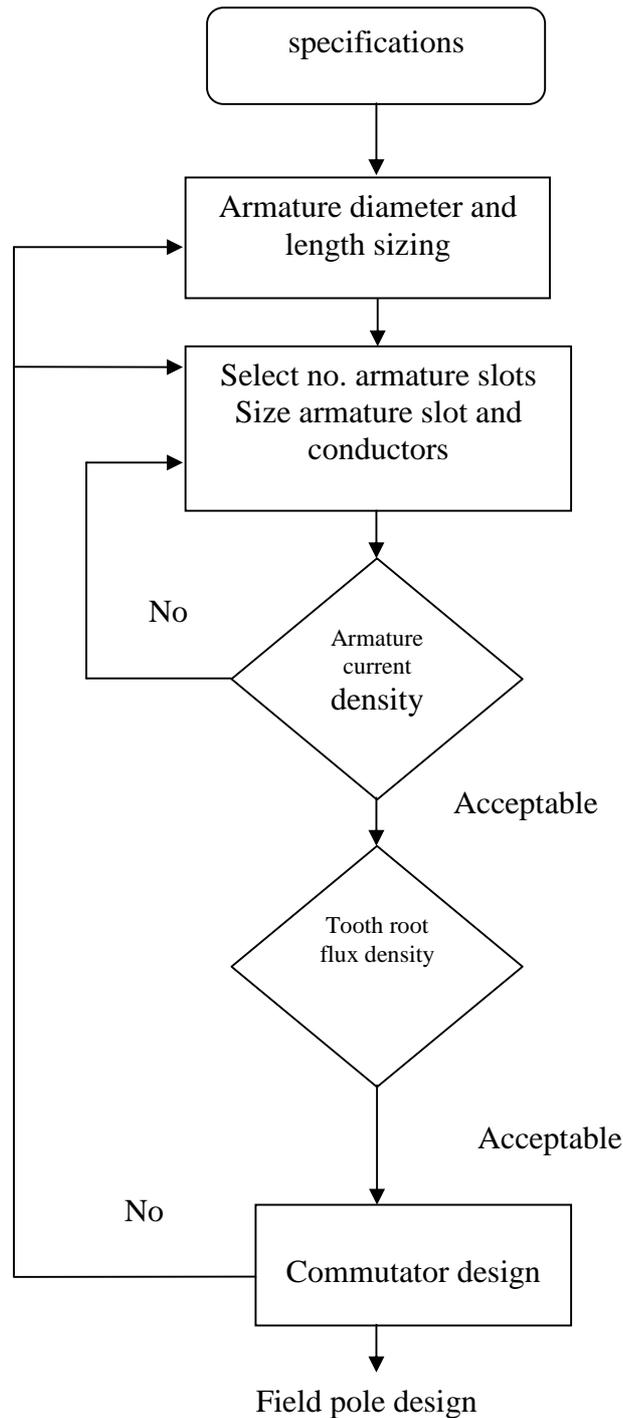


Fig .(1) Logic flowchart for armature design.

Number of Armature slots: In order to minimize flux pulsation along the pole face and produce a slot width that allows for good wedge integrity, the armature slot pitch (Y_a) should typically be in the range:

$$1 \leq Y_a = \frac{\pi d}{N} \leq 1.5 \text{ in} \quad (3)$$

Where Number of slots.

For $d < 20$ in, the lower end of the range usually results in better design ^[14].

2.2- Field pole Design:

Prior to design of the actual field pole, two items must be addressed – air gap length and frame thickness. The air gap length (δ) increases with armature diameter and can be decided by

$$\delta = 0.0335\sqrt{d} \quad (4)$$

The field pole design is generally not an iterative process. The logic flowchart of **Figure. (2)** shows the simple single-pass approach.

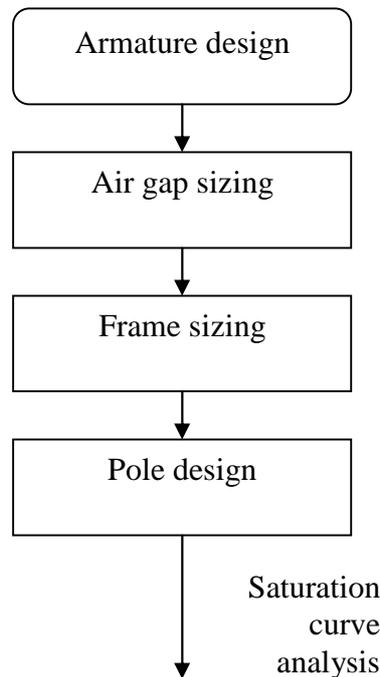


Fig .(2) The logic flowchart of the simple single-pass approach

2.3- Field winding design:

Once the magnetization curve has been calculated, the value of m.m.f. to produce flux per pole can be determined. At least 1.05 m.m.f. should be used as m.m.f. in field winding design to allow for armature reaction. Any field winding arrangement design can be design to produce m.m.f. as long as the winding will physically fit into the available space surrounding the field pole. A layout drawing of the field pole and frame is usually necessary to determine the space availability. The space available is further diminished with the addition of the inter poles and their associated windings.

The MATLAB program is formulated to read the Open Circuit Characteristic (O.C.C.) which provide from equation (1), enhanced of field pole and armature dimensions design, then has been saved in m-file. The program execution must plots the speed-torque,

speed-current, and speed-efficiency curves for the motor to allow assessment with regard to performance specifications. Should the motor not meet the desired performance, then the design must be iterated as indicated by **Figure. (3)**.

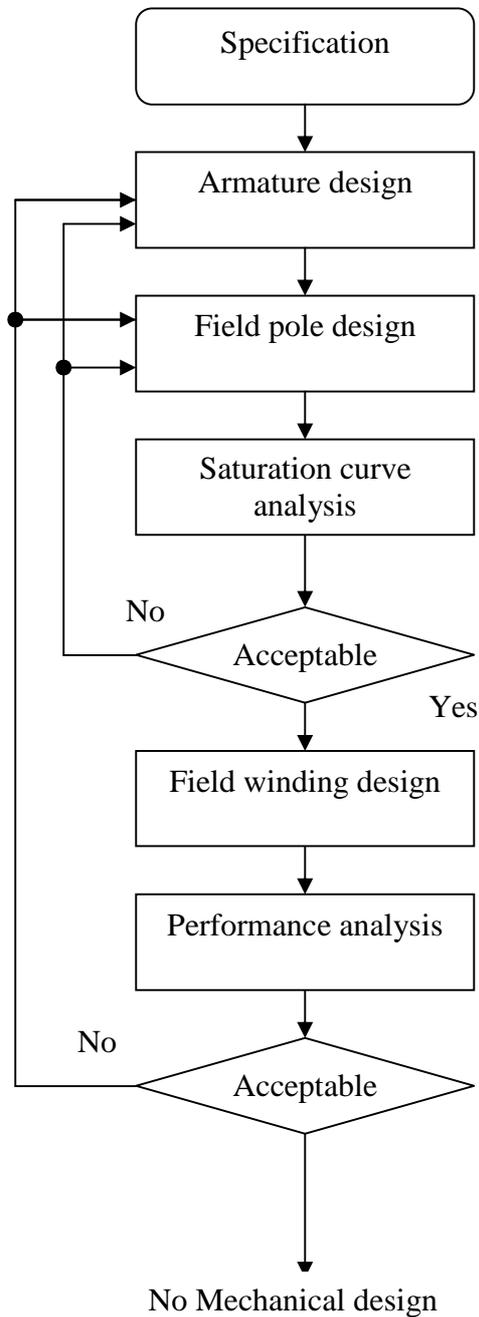


Fig .(3) Logic flowchart for D.C. motor design.

3. The Educational Use of the Models

This describes how the proposed Program was used in a senior level machinery course. This course is a step by step design that offers both selection of magnetization curve, desired rated power, speed, and calculated parameters according to specified limit to show the dynamic operation principles mathematical model parameters and characteristics of D.C. machines. Course are the structure of D.C. machines, per-phase equivalent circuit model, torque- speed characteristic, point of operation and efficiency. Compare them with the theoretical results learned from the lecture. Students through this exercise should have a basic understanding of the construction and dimensions of frame, armature and rotor also the point of operation of D.C. motors and their applications.

4. D.C. Shunt Motor Design Program Results:

The MATLAB program (m.file) is formulated to read the Open Circuit Characteristic (O.C.C.) that has been saved in another (m.file). The program then plots the speed-torque, speed-current, and speed-efficiency curves for the motor design to allow assessment with the regard to performance specifications. Should the motor not meet the desired performance, then the design must be iterated as indicated by **Figure.(3)**

The shunt d.c. motor to be designed is specified as follows:

500 V 400 hp 1750 r.p.m. 583AT frame

full-load Efficiency-94% Self ventilated

Max. speed-2500r.p.m.

Figure (4) shows Magnetization Curve which explain the relationship between the flux per pole verses Ampere turns per pole for the selected core material from which we can determine the relative permeability.

Figure (5) give us Speed-Torque characteristics for shunt D.C. motor as expected there is a slight change in the speed of a shunt motor from no-load to full-load. Hence it is essentially a constant speed motor. **Figures (6a-b)** Speed-output power and Speed-Efficiency respectively, which clearly explained the inverse relationship between speed and out power, logical analysis to that is as speed increased rotational losses (mechanical and core losses) be increased (directly proportional to frequency) and output power decreased as well as efficiency.

5. Conclusions

Program models of DC shunt motor design method have been developed using MATLAB program (m. file). It has been shown that proposed program models correctly predict the effect of armature design, field pole design, and saturation curve on the torque-speed characteristic of the DC motor. Furthermore, program have been successfully integrated into an electric machinery course as a part of the software laboratory. The teaching of both the selection of magnetization curve, characteristics and dynamic analysis of DC motors has been enhanced using the programming (m.file). Program helps students increase their understanding of DC motor operation, fundamentals of dynamic system.

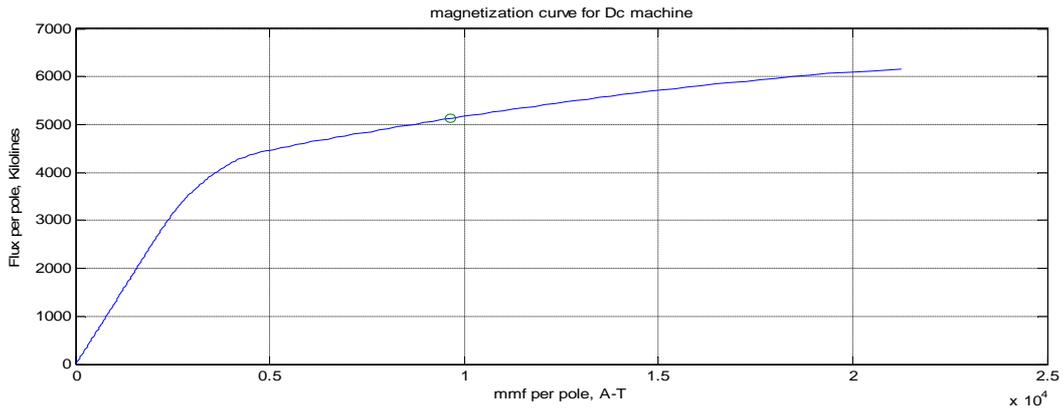


Fig .(4) magnetization curve of selection D.C. shunt motor.

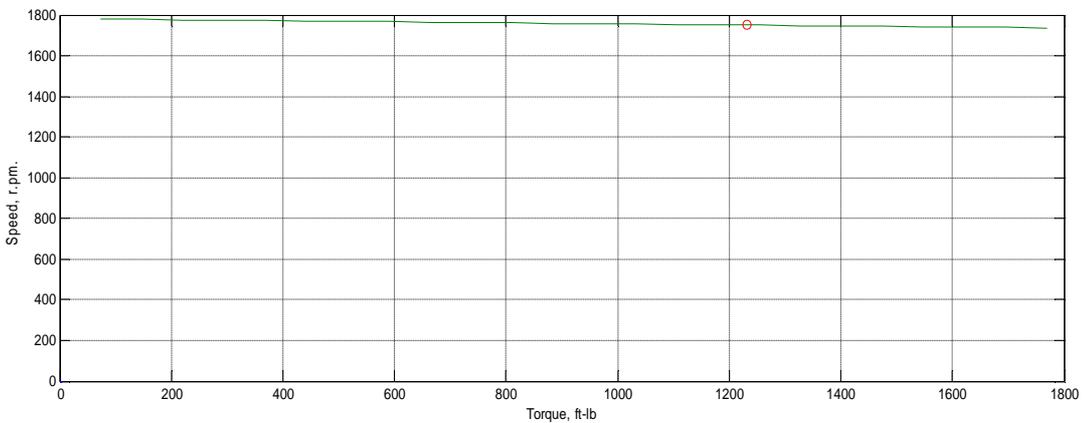
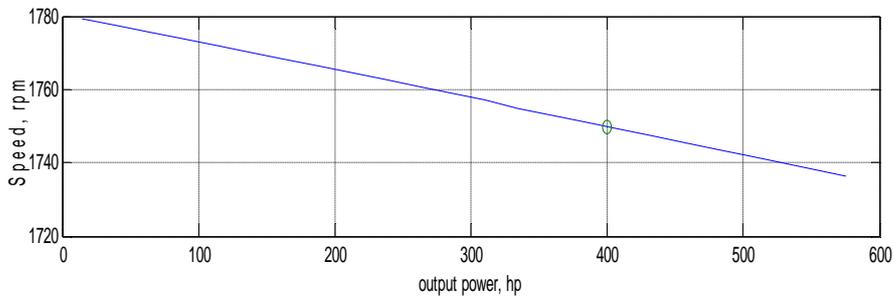


Fig .(5) speed versus torque relationship.

(a)



(b)

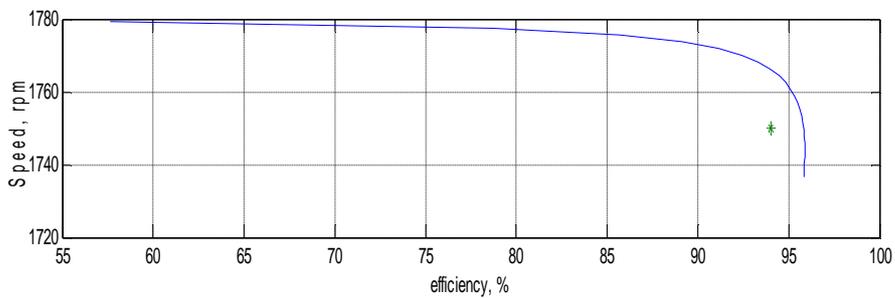


Fig .(6) shows characteristics of shunt D.C. motor a- the speed versus output power, b- efficiency relationship respectively.

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