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Determination of Moment of Inertia of Electrical Machines Using MATLAB

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***Abstract*:- This paper explain determination of moment of inertia of electrical machine using retardation test using analytically and simulated using MATLAB Software. Mechanical power losses versus speed characteristic which show the dependency on the speed.**

I. INTRODUCTION

The moment of inertia and mechanical losses in electrical machines are playing significance role in improving the performance of electrical machine from performance point of view. The moment of inertia cab be calculated if the main dimension of the electrical machine is known, Fig. 1 show that armature or stator diameter *(D)* and armature length *(L)* of the electrical machine.

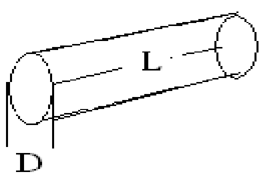

Fig. 1 Main dimension of electrical machine

In the absence of main dimension of the electrical machine it can be calculated by performing certain test on machine. The most common methods of experiment to determine moment of inertia of electrical machine are torsion oscillation test, pendulum test, retardation test .

In case of torsion oscillation, rotor is removed and vertically suspended from the wire. Transmit the rotor an oscillation around its axis and is determined the period of complete oscillation.[2]

The pendulum test , consists in fit up a pendulum of mass *m* at the end of a bar with length *l* on the rotor axis. This system is put in motion and is determine the period of oscillation (*T)*[2]. This paper explain the MATLAB simulation of retardation test on electrical machine which is simple and easy to performed in laboratory as compared with the torsion oscillation test and pendulum test.[1],[4],[6],[8].

I. DETERMINATION OF MOMENT OF INERTIA

In order to determine moment of inertia of electrical machine using retardation test , electrical machine is rotated at a speed higher than rated speed , then machine is let free to slow down to stand still. Deceleration curve is obtained which varies with time is shown in Fig.2.

This test can be performed on the dc separately excited motor or a synchronous motor with field is on . In case of wound rotor induction motor this test is carried out by keeping the stator supply and opening the rotor winding connection.

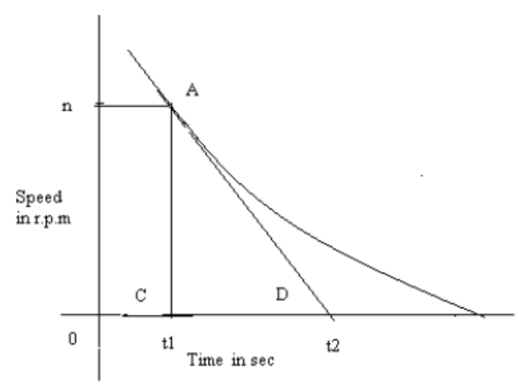

Fig. 2. Deceleration curve

The energy is used up in supplying the rotational loss when system rotate , slowing down gradually and then stops. The power consumed in overcoming the losses due to rotation is given by equation (1).

$$P_m = \frac{d\left(\frac{1}{2} J\omega^2{}_m\right)}{dt} \qquad (1)$$

Where *Pm* is consumed in supplying rotational losses at any speed ω_m . The equation (1) can be written as at rated speed .

$$P_{mn} = J\left(\frac{\pi}{30}\right)^2 n_n \left(\frac{dn}{dt}\right)_{n=n_n} \qquad (2)$$

Where n_n is the rated speed, the derivative $\left(\frac{dn}{dt}\right)_{n=n_n}$ can be obtained from the deceleration curve as shown in Fig.2. P_{mn} is the mechanical losses at the rated speed, from equation (2) , the equation for moment of inertia is given by (3).

$$J = \frac{P_{mn}}{\left(\frac{\pi}{30}\right)^2 n_n \left(\frac{dn}{dt}\right)_{n=n_n}} \qquad (3)$$

To determine moment of inertia , apart from the deceleration cure mechanical losses must be known , mechanical losses can be find out by well known method of segregation of losses[9],[10].Thereby machine is supplied with the constant voltage supply (V). Current (I) and power (P) is varied at different value of supply voltage; the power balance equation is given by

$$P_{in} = P_j + P_{fe} + P_m \qquad (4)$$

From above equation ,

$$P_{fe} + P_m = P_{in} - P_j \qquad (5)$$

Where P_{fe} I s iron losses, P_m is mechanical losses and P_j is $I^2 R$ losses. Core losses are directly proportional to square of supply voltage but mechanical losses are not depend on the voltage. Here , core losses are segregated from the characteristic given by

$$P_{fe} + P_m = f(V^2) \qquad (6)$$

The point at which characteristic (6) intersect the power axis gives the value of mechanical losses .

II. MECHANICAL POWER LOSSES AND SPEED

Mechanical power losses are directly proportional to the square of speed[7],[8],[9]. This dependence is not rigorously reflecting the reality for low speeds and speeds under rated speed it given by

$$P_m(n^i) = K n_i^{p_i} \qquad (7)$$

On the other hand, from the machine motion equation (2) after computing the moment of inertia *J*, the mechanical power losses can be determined, as follows:

$$P_m(n_i) = J\left(\frac{\pi}{30}\right)^2 n_i \left(\frac{dn}{dt}\right)_{n=n_i} \qquad (8)$$

The proportionality coefficient *k* is determined from previous relation, taking into account that for $n_i = n_n$ $p_i = 2$. The mechanical power losses versus speed curve can be obtained by using equation (7).

III. MATLAB SIMULINK RESULT

The moment of inertia was obtained by implementing the all above equation in matlab model as shown in Fig.3, where the simulation is done using the induction motor with the following rated data.

P = 3 [kW] ; *V* = 400 [V] ; *I* = 6.76 [A], n_n = 1412 [r.p.m.].

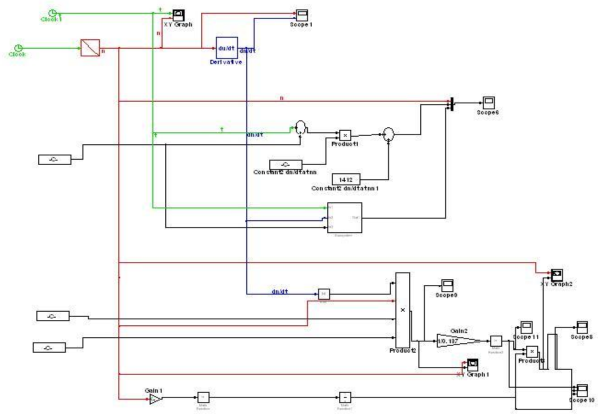

Fig. 3. Matlab Simulink Model for Retardation Test

In the Fig. 4 is present deceleration curve where induction motor is run at speed higher than the rated speed n_n = 1412 [r.p.m.] to a speed n = 2500 [r.p.m]

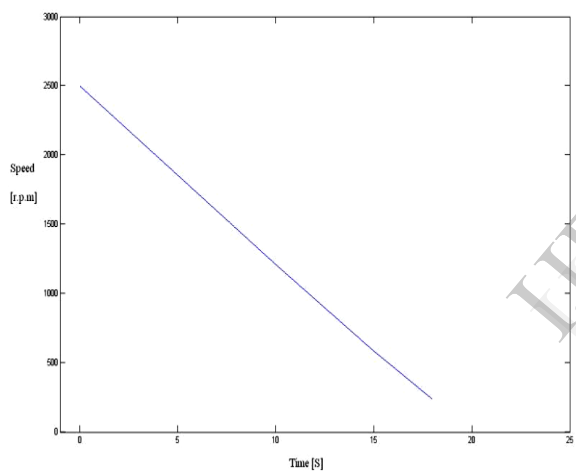

Fig. 4. Deceleration curve

The value of speed derivative is

$$\left(\frac{dn}{dt}\right)_{n=n_n} = 129.38 \text{ [rot/s}^2\text{]}$$

The mechanical power losses are depend on the speed is obtained which shown in the Fig.5, the mechanical power losses at the rated speed is

$$Pm = 152\text{[W]}.$$

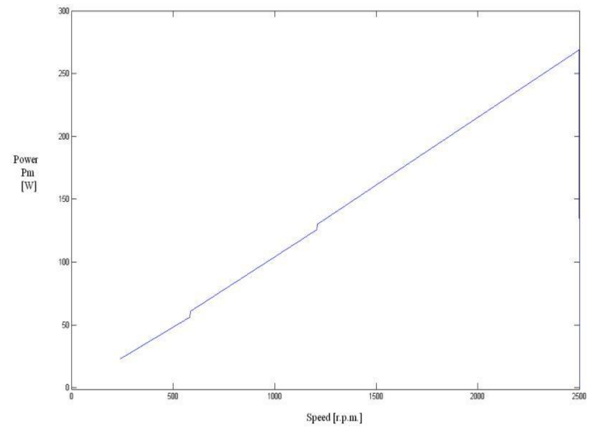

Fig.5. Mechanical losses vs. Speed

Taking into account the equation (3) , mechanical power losses and the value of speed derivative , the moment of inertia of the induction motor is

$$J = 0.0760 \text{ [Kg. m}^2\text{]}$$

The value of proportionality coefficient can be computed using (9) and taking into account that for rated speed n_n and pi =2.

$$K= 0.137$$

IV. CONCLUSIONS

It is easy to determine the moment of inertia using the retardation test after data acquisition and numerical computation. The mechanical losses are need to be obtained from the method of segregation of losses and from equation (7) ; mechanical losses of the machine depend on the square of speed only close to rated speed values.. it can be noticed that mechanical power losses change significantly with speed as shown in Fig. (5) , taking into account this speed dependency.

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