

Detection of Eccentricity Fault for Induction Motor

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Abstract

The study shows that 80% of faults are because of eccentricity in induction motors, advancing numerous research endeavors still gave to the eccentricity in these motors. In this paper, an asynchronous motor under static and dynamic eccentricities with various load levels is modeled utilizing using finite element method (FEM) as FEM is utilized as an intense numerical technique for analysis of defective induction motors. The simulation outcomes demonstrate that due to non-uniform air gap, flux distortion will occur that cause distortion in torque, flux, voltage and power in terms of fluctuations and mechanical vibrations. The simulation work was directed utilizing a three phase 5kW, 415V rating induction motor is composed utilizing Rmxpert and Maxwell transient approach is used for FEM analysis.

Keywords: Eccentricity, fault diagnosis, induction motor, maxwell 2D

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INTRODUCTION

Induction motors are also known as the asynchronous motors and they are the most used electric drive in industrial applications. (IM) are widespread electromechanical conversion systems for high-dynamic performance applications. The structure of induction motors consists of the stator, rotor, and mechanical parts. The common faults in the stator of an induction motor include turn-to-turn fault, coil-to-coil short-circuit, phase-to-phase short-circuit, open-circuit of stator windings, phase-to-ground short-circuit, and a deficit of insulation. Various faults on the rotor of an induction motor include broken

rotor bars and broken end-rings. Finally, different types of mechanical faults include bearing faults and eccentricity of the stator and rotor (Figure 1).

Now it covers most of the transformation needs of electrical energy to mechanical energy. Since, it has the advantage of being robust, simple and low cost. However, the fault diagnosis of such machines has become an essential and necessary task to get a well-functioning of a more secured production chain for most industrial applications. Also, the production lines must be provided with effective protection systems since any failure

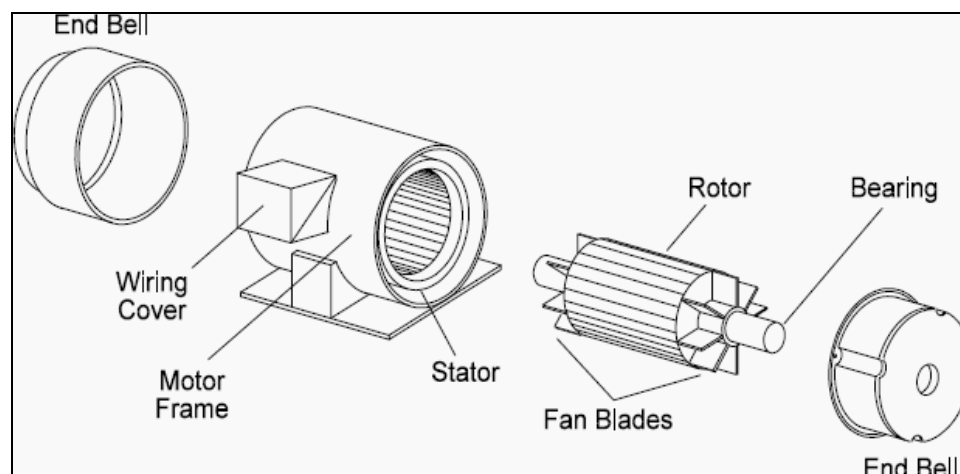


Fig. 1: Basic Construction of Induction Motors.

can cause hardware damage and/or body. To avoid such problems, many researchers are still working to develop various dynamic models for analysis and fault diagnosis purpose of the induction motor (Figures 2–7).

MATHEMATICAL MODELING OF INDUCTION MOTOR

The proposed model is based on an approximation of coupled field circuits' approach where the magnetic current in each mesh of the rotor cage is an independent variable as shown in Figure 2.

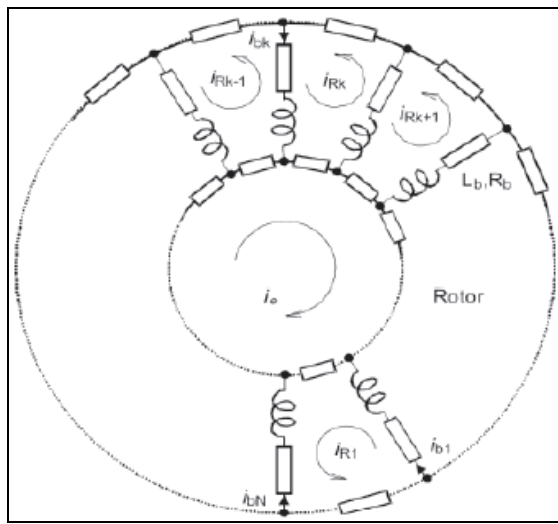


Fig. 2: Equivalent Rotor Mesh Circuit.

This approach offers a compromise in terms of model accuracy and computation time. In addition to that, this type of model can take into account a number of electromagnetic faults such as broken bars and eccentricity faults. By using extended Park transformation in the (d, q) frame, we obtain the mathematical model of the induction motor A. Bellini, F. Filippetti, C. Tassoni (2008); S. Nandi, R. M. Bharadwaj, and H. A. Toliyat (2002); W. T. Thomson and A. Barbour (1998) which takes into account the failure of the rotor and can be written as:

$$[L] \frac{d[I]}{dt} = [V] - [R][I].$$

$$[I] = [I_{ds} \quad I_{qs} \quad I_{dr} \quad I_{qr}]^T \quad (1)$$

$$[V] = [V_{ds} \quad V_{qs} \quad V_{dr} = 0 \quad V_{qr} = 0]^T$$

$$[L] = \begin{bmatrix} L_{sc} & 0 & \frac{-N_r}{2} M_{sr} & 0 & 0 \\ 0 & L_{sc} & 0 & \frac{-N_r}{2} M_{sr} & 0 \\ \frac{-3}{2} M_{sr} & 0 & L_{rc} & 0 & 0 \\ 0 & \frac{-3}{2} M_{sr} & 0 & L_{rc} & 0 \\ 0 & 0 & 0 & 0 & L_e \end{bmatrix} \quad (2)$$

$$\text{and } L_{sc} = \frac{6 \cdot \mu_0 \cdot N_s^2 \cdot r \cdot l}{e \cdot \Pi \cdot p^2} + L_s \quad (3)$$

Where,

L_{sc} : is the total inductance, e : air gap of the machine, L_s : leakage inductances, r : mean radius of the machine, l : length of the machine and μ_0 : air permeability.

$$[R] = \begin{bmatrix} R_s & -\omega L_{sc} & 0 & \frac{-N_r}{2} \cdot \omega M_{sr} & 0 \\ \omega L_{sc} & R_s & \frac{-N_r}{2} \cdot \omega M_{sr} & 0 & 0 \\ 0 & 0 & R_r & 0 & 0 \\ 0 & 0 & 0 & R_r & 0 \\ 0 & 0 & 0 & 0 & R_e \end{bmatrix} \quad (4)$$

$$R_r = L_{rp} + \frac{2L_e}{N_r} + 2R_b(1 - \cos(\alpha)) \quad (5)$$

$$L_{rc} = L_{rp} - M_{rr} + \frac{2L_e}{N_r} + 2L_e(1 - \cos(\alpha)) \quad (6)$$

After applying the extended Park transformation on the expression of electromagnetic torque, the mechanical part is ultimately determined by the relationship obtained below

$$\frac{d\omega}{dt} = \frac{1}{J} (T_e - T_r - f_v \cdot \omega) \quad (7)$$

$$T_e = \frac{3}{2} \cdot p \cdot N_r \cdot M_{sp} \cdot (I_{ds} \cdot I_{qr} - I_{qs} \cdot I_{dr}) \quad (8)$$

Where p : is pole number, N_r : number of rotor bar, M_{sr} : Mutual inductance.

ECCENTRICITY FAULTS

Eccentricity is a common mechanical fault in the electrical machine. Approximately, 80% of

the mechanical faults lead to the eccentricity. Eccentricity fault may occur during the manufacturing and assembling process. Eccentricity exists when there is a nonuniform distance between the rotor and stator in the air-gap.

There are two types of eccentricity faults: static eccentricity and dynamic eccentricity and a combination of both are mixed eccentricity.

In the static eccentricity, the symmetrical axis of rotor coincides with the rotational axis of the rotor, but it is displaced from the stator symmetrical axis. In this case, air-gap distribution is nonuniform around the rotor but the minimum air-gap angular position is fixed. Static eccentricity fault is created by shifting the stator geometry.

Dynamic eccentricity means that the rotor is rotating on the stator bore axis but not on its own axis. The off-center axis of rotation spin along a circular path with the same speed as

the rotor does. This kind of eccentricity may be caused by a bent shaft, mechanical resonances, bearing wear or movement, or even static eccentricity.

ANALYZING HEALTHY AND FAULTY CONDITIONS

The simulation work was conducted on a three-phase induction motor having specifications given in Table 1, is designed using Rmxpert and Maxwell is used for FEM analysis. The proposed model of the induction motor is shown in Figure 5.

Table 1: Specifications of modeled three-phase induction motor used.

Parameters	Value
Phase	3 Phase IM
Rated Power	5kW
Rated Voltage	415V
Frequency	50Hz
Number of poles	4

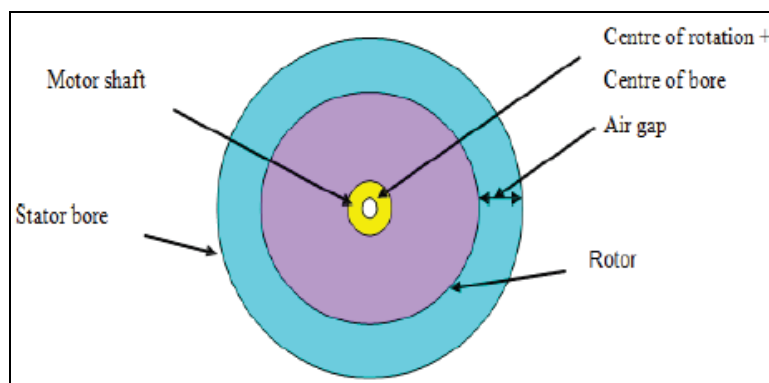


Fig. 3: Healthy Induction Motor.

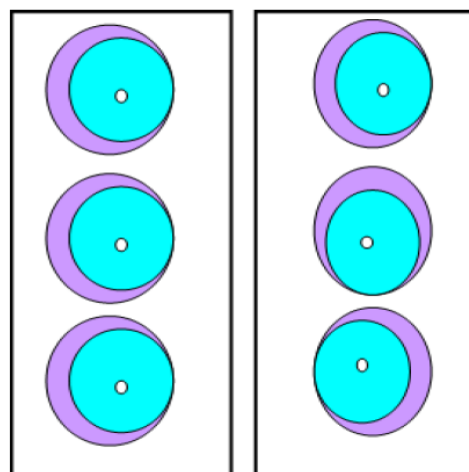


Fig. 4: (a) Static Eccentricity. (b) Dynamic Eccentricity.

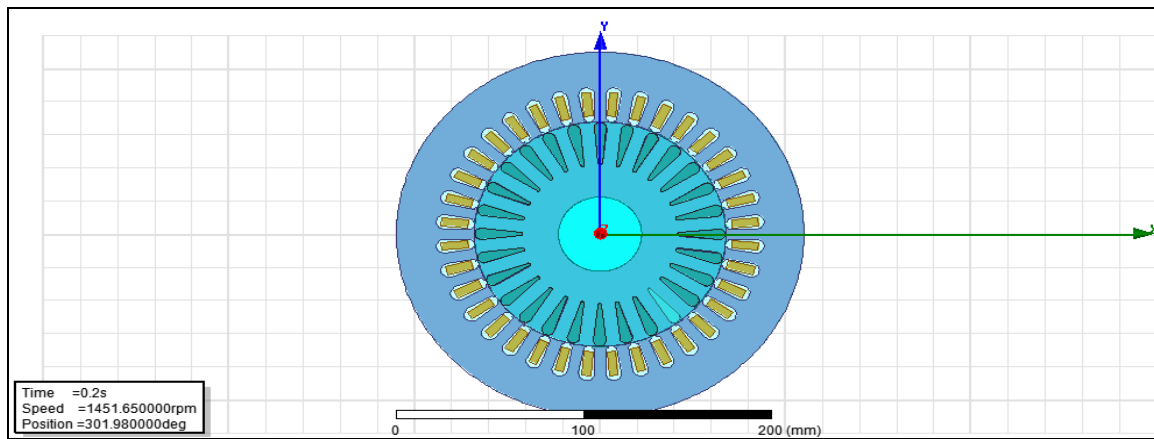


Fig. 5: Proposed model of the induction motor.

Here we have simulated a 3 phase induction motor under various conditions of static and dynamic eccentricity, and the results are shown. All the conditions for simulation that we have used are

- 4.1 Under normal condition
- 4.2 Fault condition with 34.48% dynamic eccentricity
- 4.3 Fault condition with 27.58% dynamic eccentricity
- 4.4 Fault condition with 34.48% static eccentricity
- 4.5 Fault condition with 27.58% static eccentricity

Induction Motor under Normal Condition

Under normal conditions, without having any eccentricity the various results are

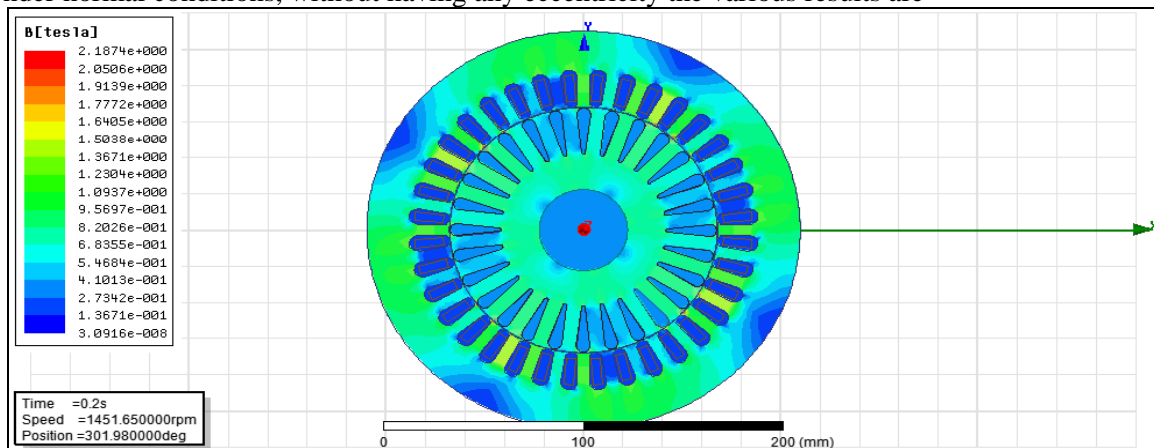


Fig. 6: (a) Flux Density Distribution under Normal Condition.

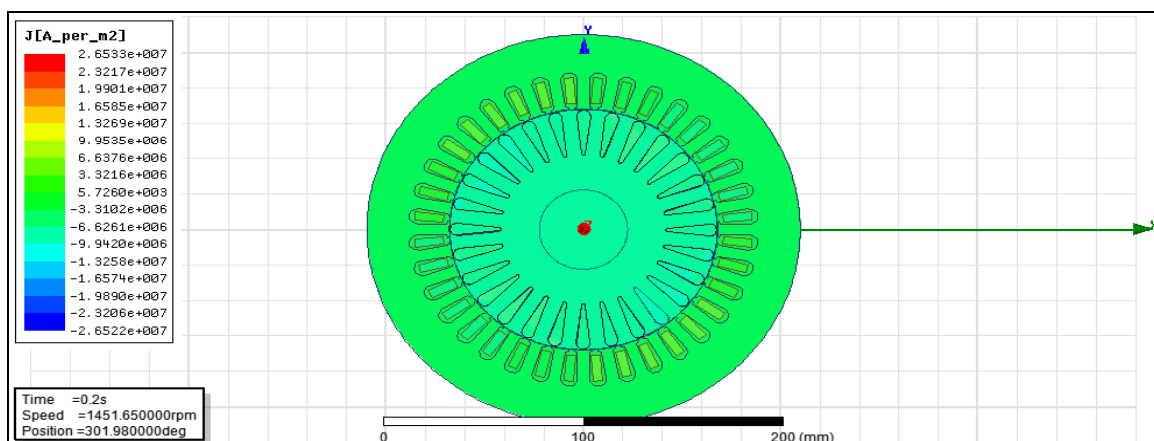


Fig. 6: (b) Current Density Plot under Normal Condition.

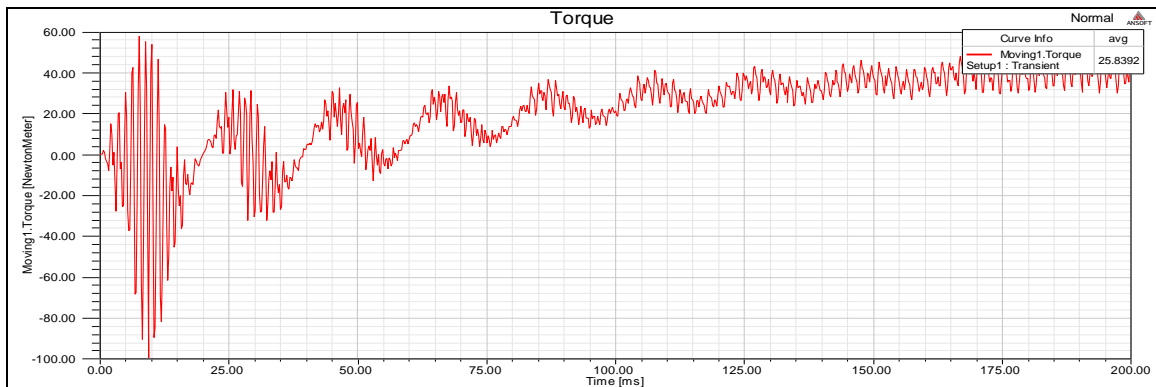


Fig. 6: (c) Torque Response Over a Period of Time.

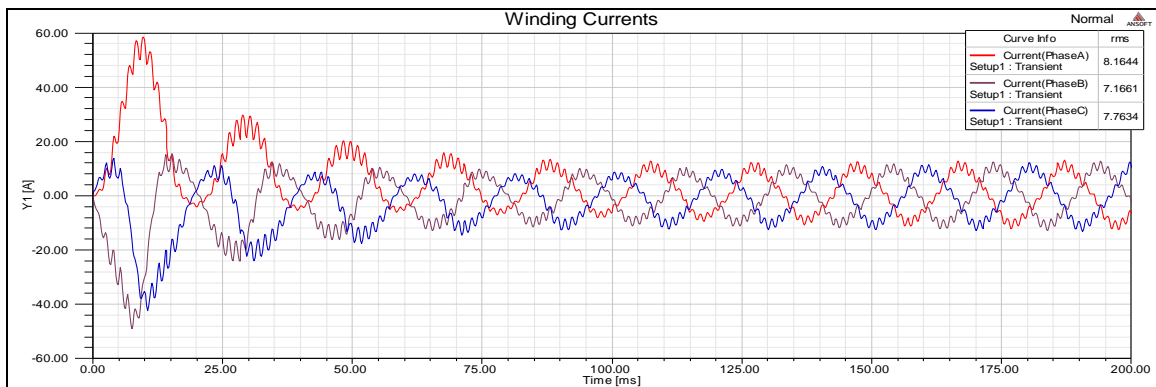


Fig. 6: (d) Current Response under Normal Condition.



Fig. 6: (e) Flux Linkage Response under Normal Condition.

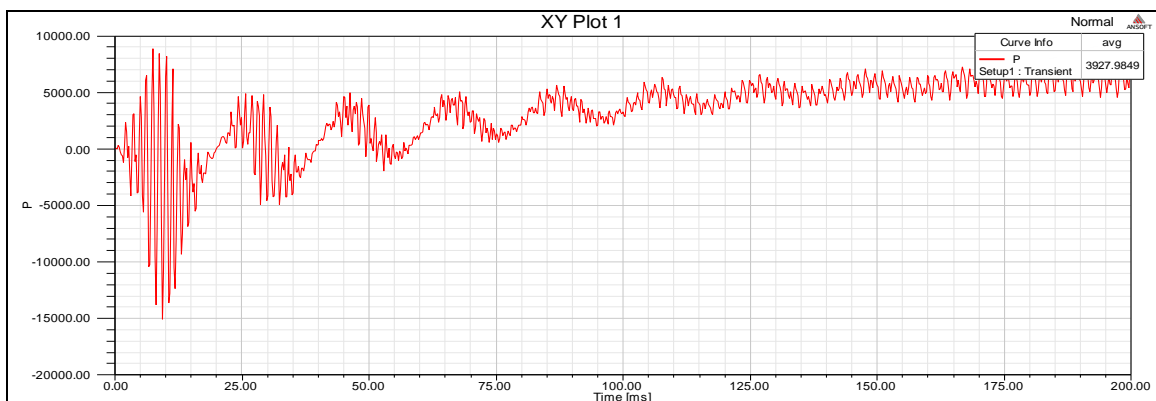


Fig. 6: (f) Output Power Response under Normal Condition.

Induction Motor Having Fault Condition With 34.48% Dynamic Eccentricity

Here we have simulated a 3 phase induction motor with 34.48% dynamic eccentricity and

the results have been shown. The nominal air gap in the designed motor is 0.29. So, for creating 34.48 dynamic eccentricities along x-axis required shift distance is 0.1mm.

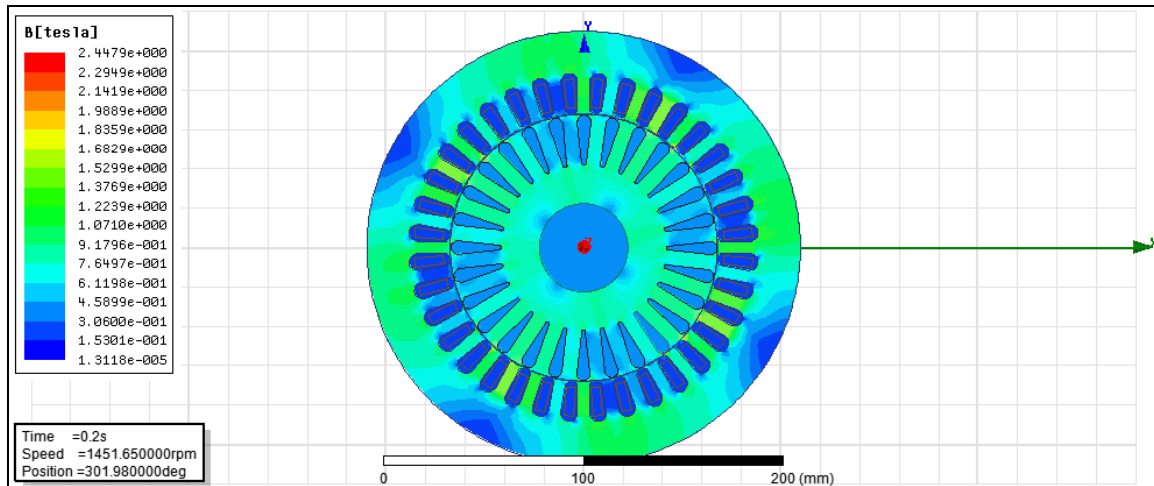


Fig. 7: (a) Flux Density Distribution with 34.48% Dynamic Eccentricity.

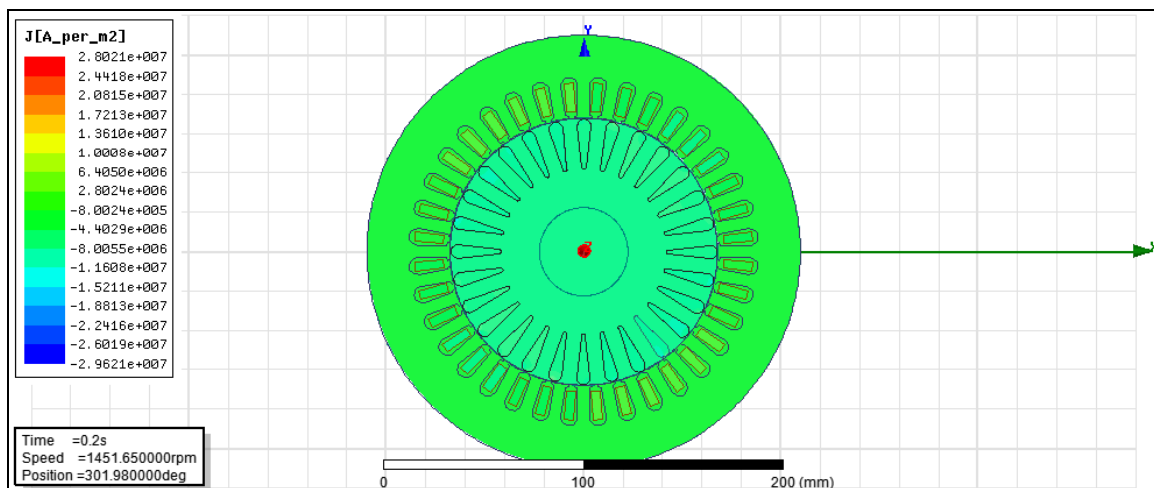


Fig. 7: (b) Current Density Distribution with 34.48% Dynamic Eccentricity.

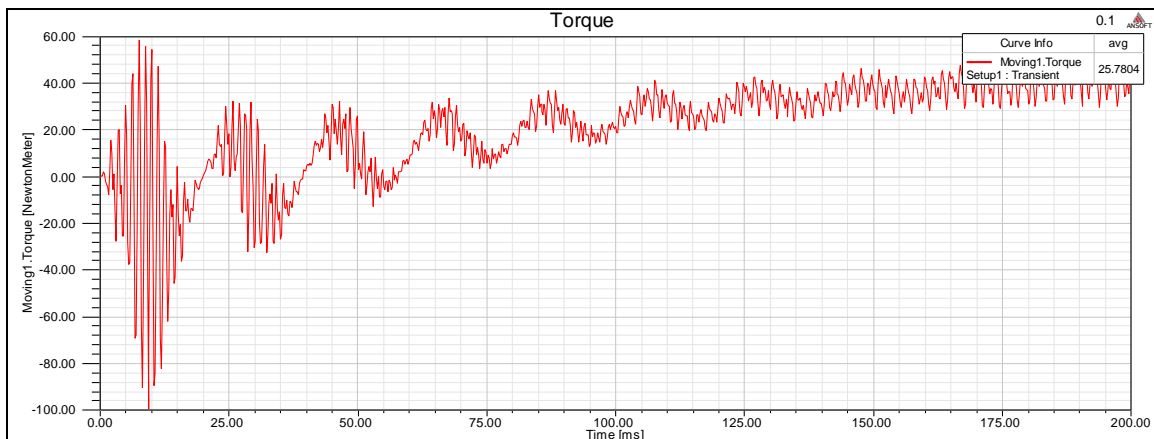


Fig. 7: (c) Torque Response of Induction Motor with 34.48% Dynamic Eccentricity.

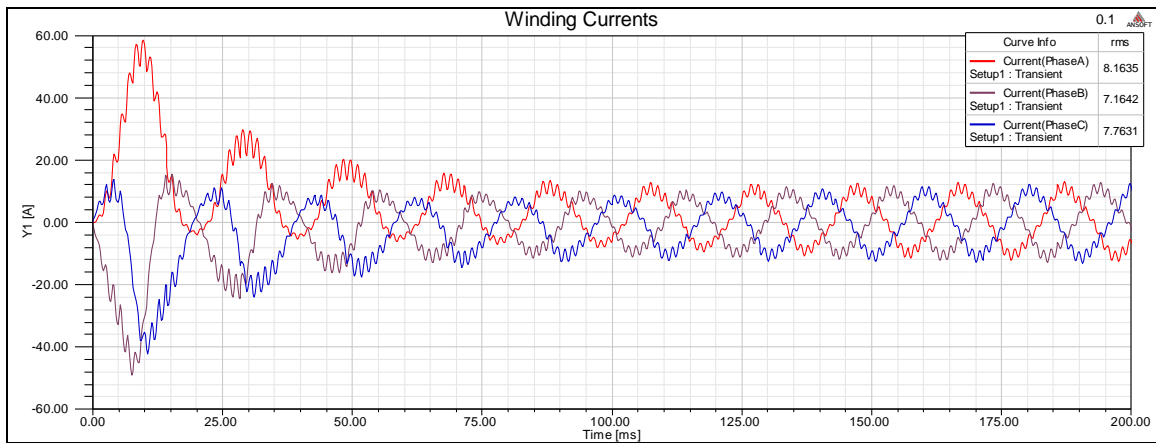


Fig. 7: (d) Current Response of Induction Motor with 34.48% Dynamic Eccentricity.

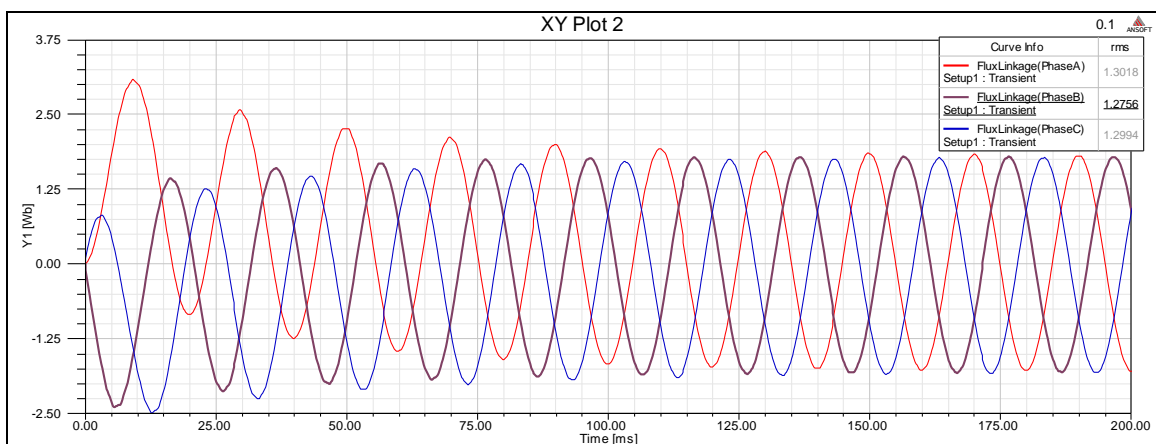


Fig. 7: (e) Flux Linkage of Induction Motor with 34.48% Dynamic Eccentricity.

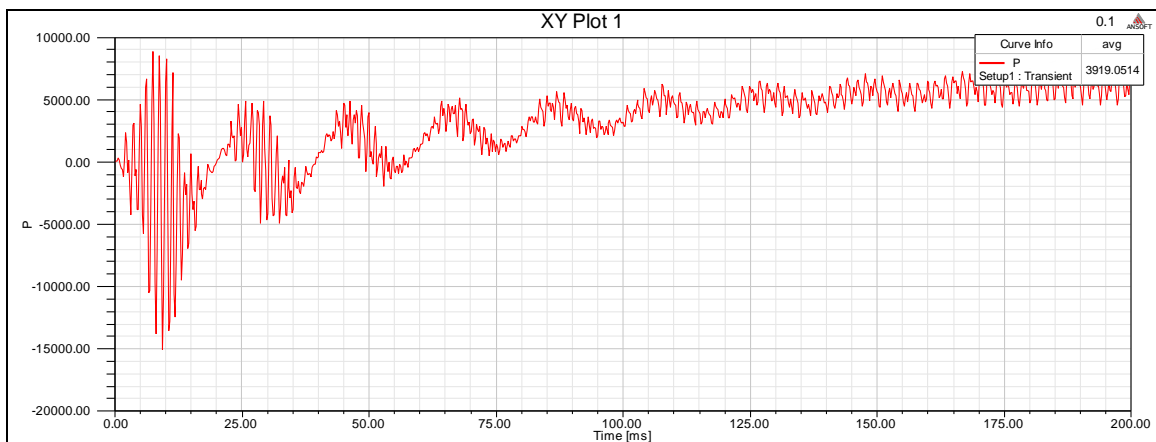


Fig. 7: (f) Output Power Response of Induction Motor with 34.48% Dynamic Eccentricity.

Induction Motor Having Fault Condition With 27.58% Dynamic Eccentricity

Here, we have simulated a three-phase induction motor with 27.58% dynamic eccentricity and the results have been shown.

The nominal air gap in the designed motor is 0.29. So, for creating 27.58% dynamic eccentricity along x-axis required shift distance is 0.08 mm as given Figures 8 (a to f).

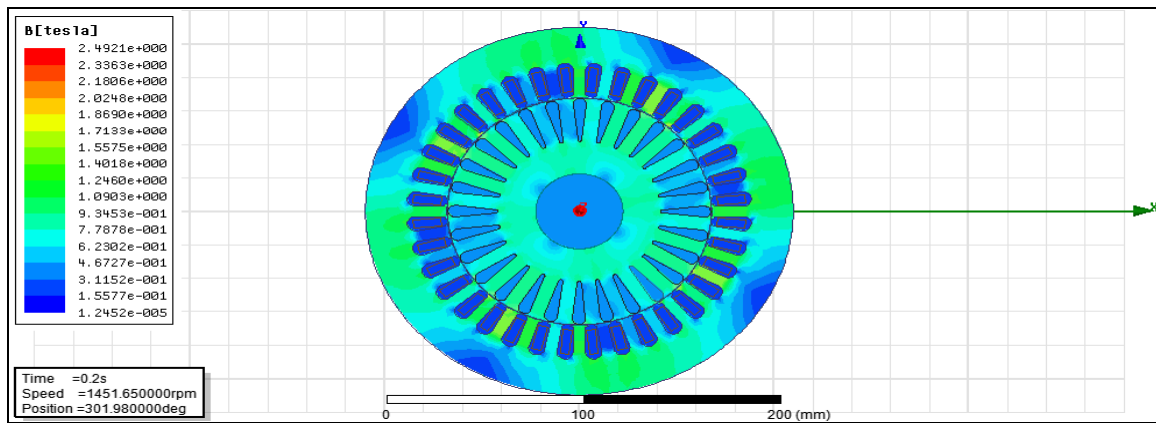


Fig. 8: (a) Flux Density Distribution with 27.58% Dynamic Eccentricity.

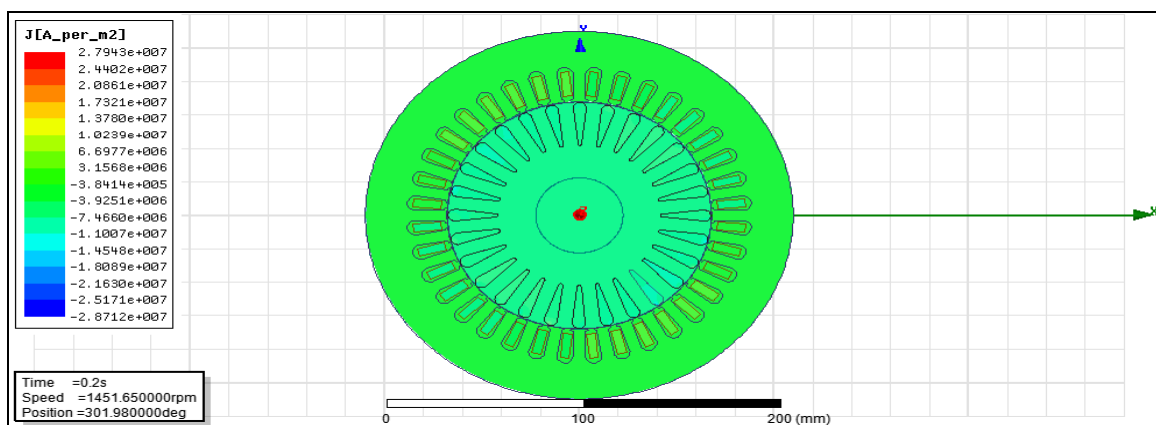


Fig. 8: (b) Current Density Distribution with 27.58% Dynamic Eccentricity.

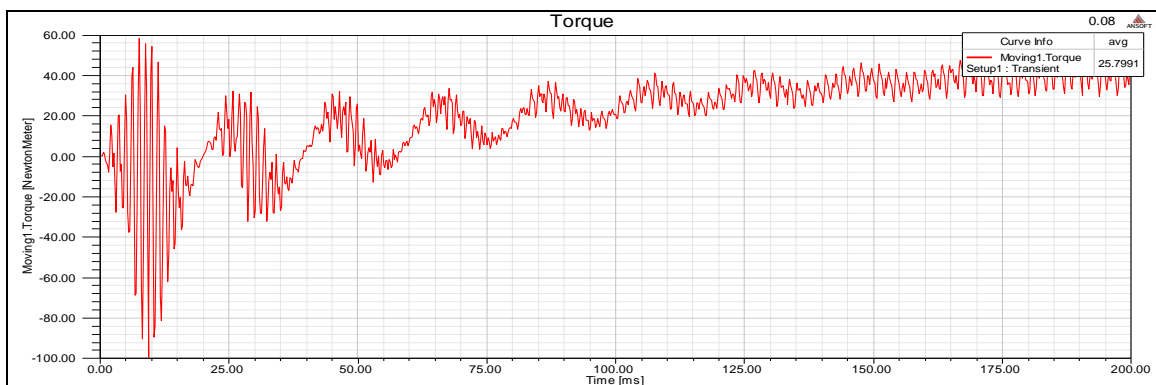


Fig. 8: (c) Torque Response of Induction Motor with 27.58% Dynamic Eccentricity.

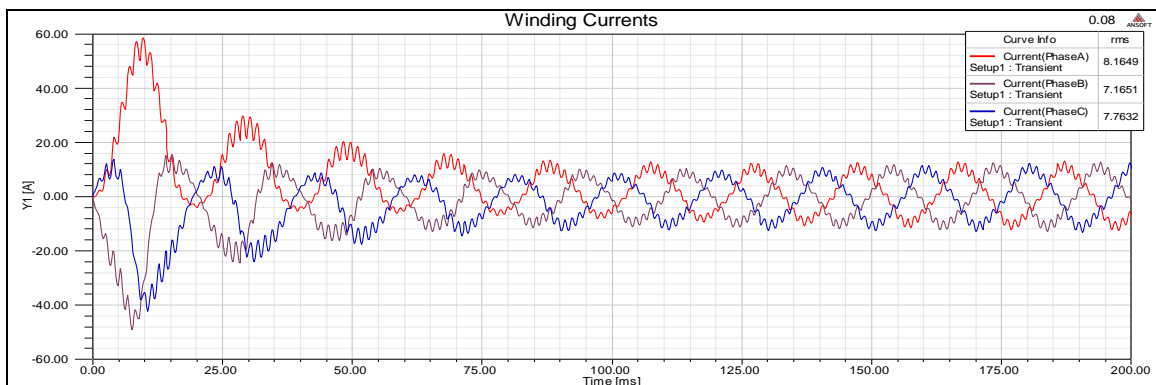


Fig. 8: (d) Current Response of Induction Motor with 27.58% Dynamic Eccentricity.

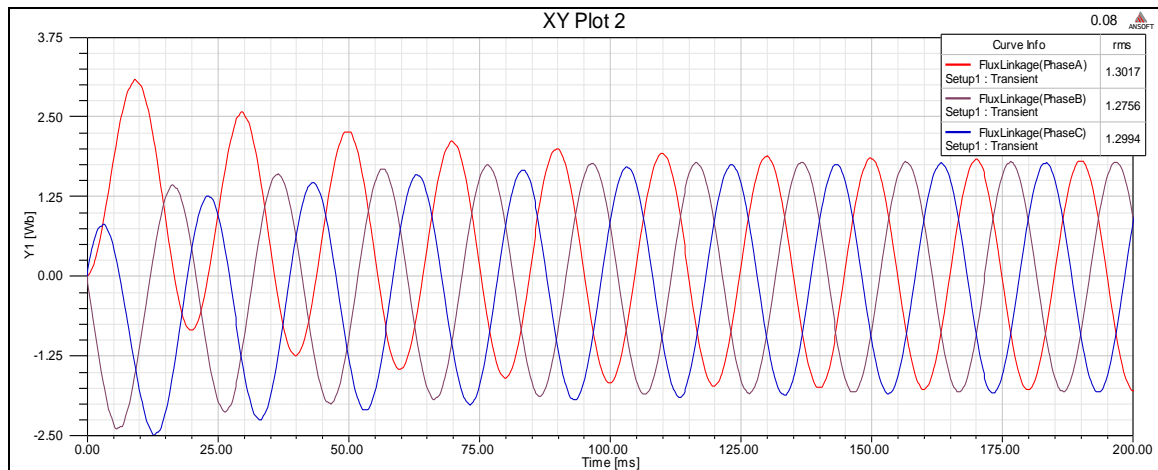


Fig. 8: (e) Flux Linkage of Induction Motor with 27.58% Dynamic Eccentricity.

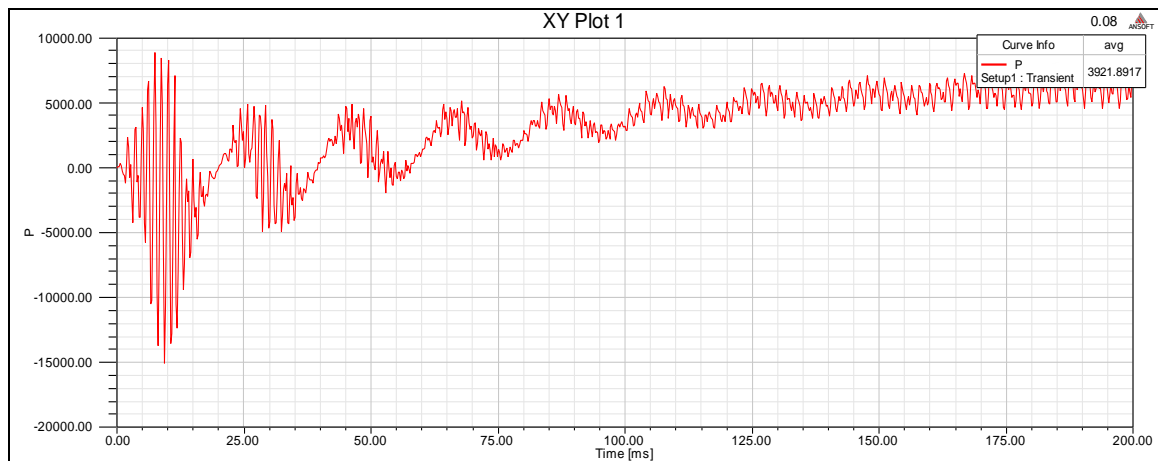


Fig. 8: (f) Output Power Response of Induction Motor with 27.58% Dynamic Eccentricity.

Induction Motor Having Fault Condition With 34.48% Static Eccentricity

The simulation results for the induction motor having fault condition of 34.48% static eccentricity are shown in Figure 9(a to f).

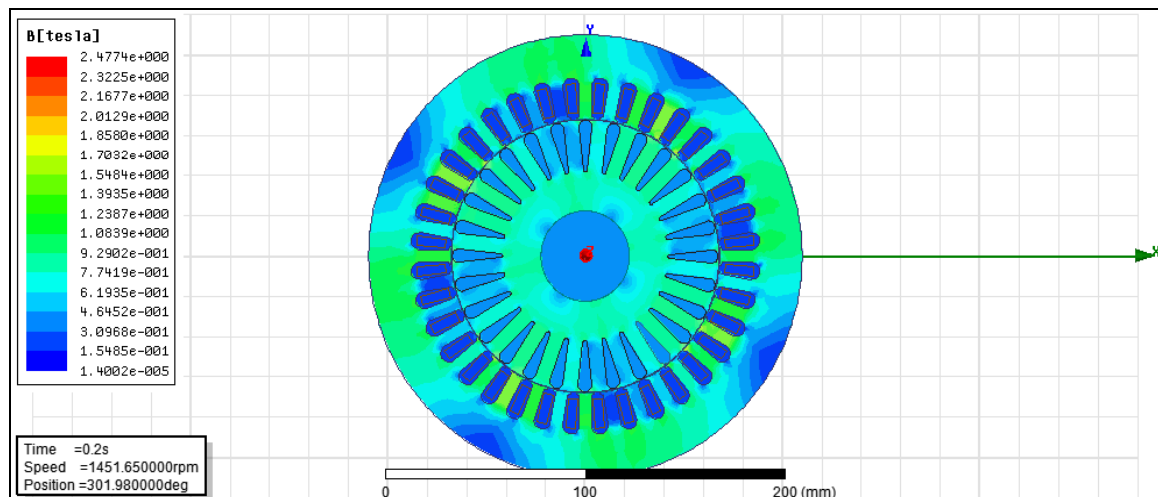


Fig. 9: (a) Flux Density Distribution with 34.48% Static Eccentricity.

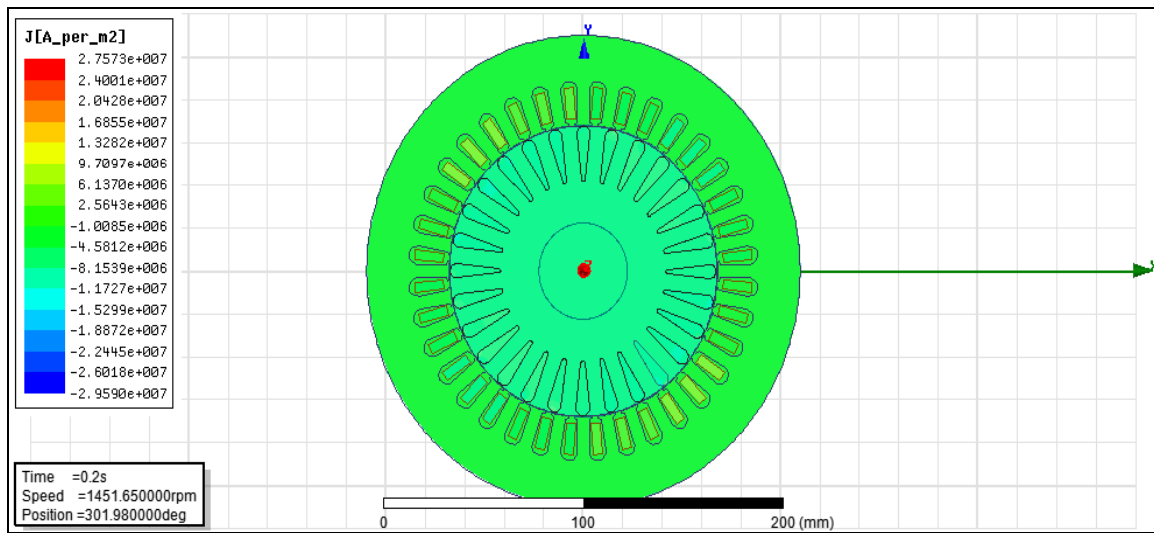


Fig. 9: (b) Current Density Distribution with 34.48% Static Eccentricity.

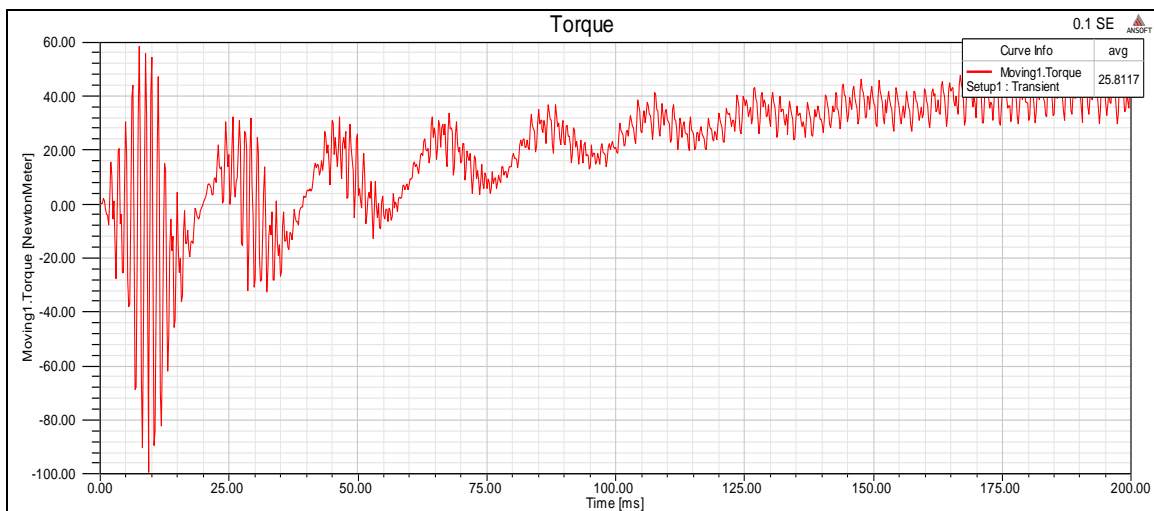


Fig. 9: (c) Torque Response of Induction Motor with 34.48% Static Eccentricity.

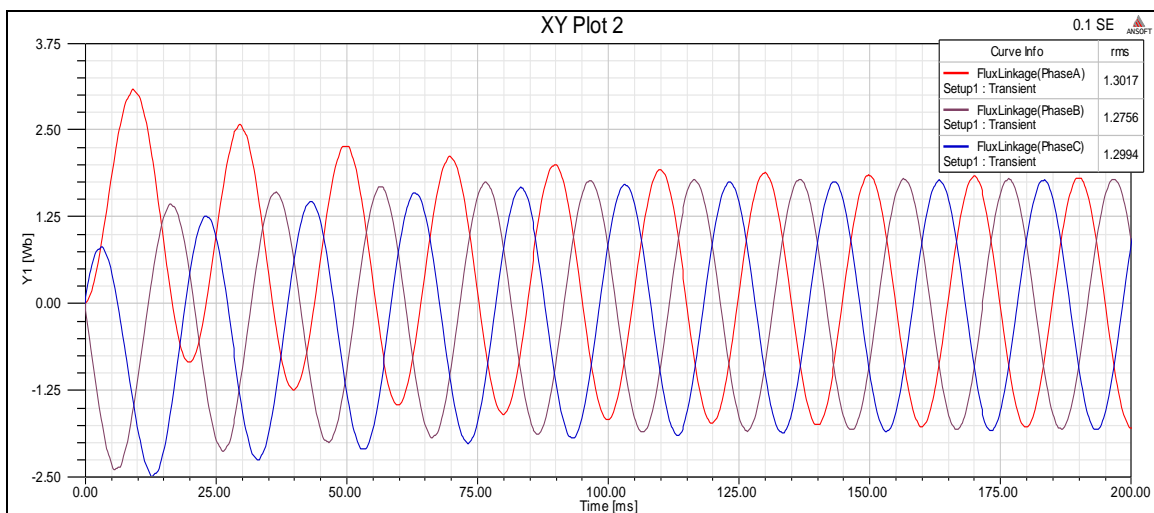


Fig. 9: (d) Flux Linkage of Induction Motor with 34.48% Static Eccentricity.

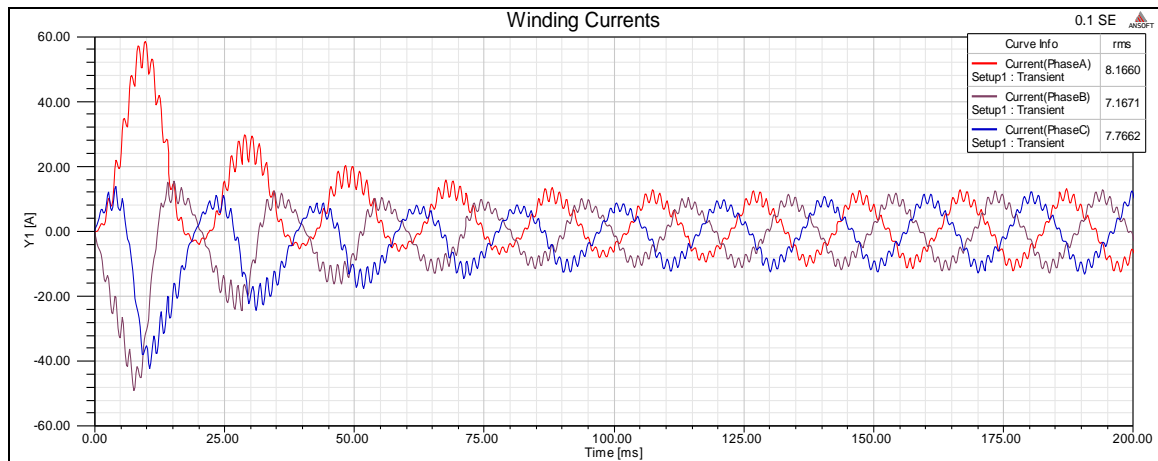


Fig. 9: (e) Current Response of Induction Motor with 34.48% Static Eccentricity.

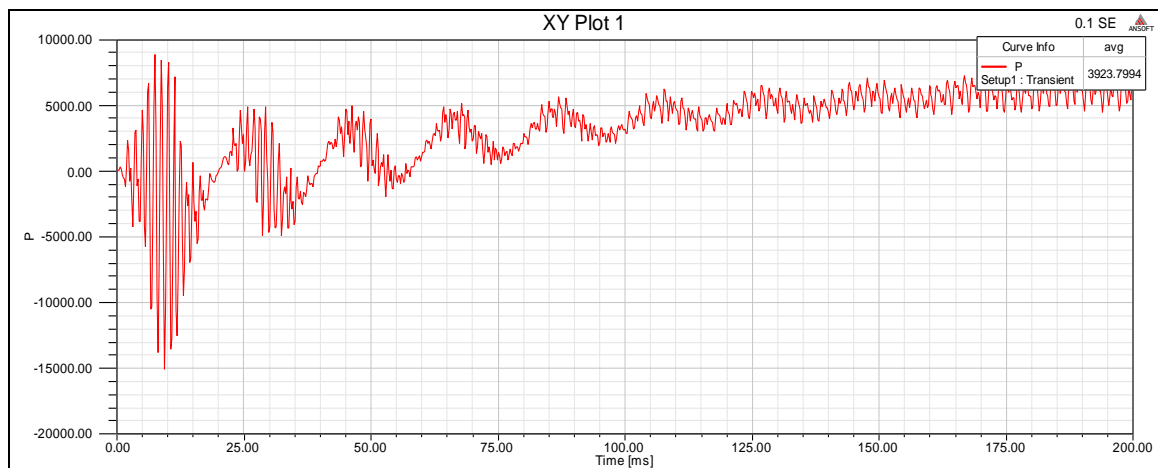


Fig. 9: (f) Output Power response of Induction Motor with 34.48% Static Eccentricity.

Induction Motor Having Fault Condition With 27.58% Static Eccentricity

The simulation results for the induction motor having fault condition of 27.58% static eccentricity are shown in Figure 10(a to f).

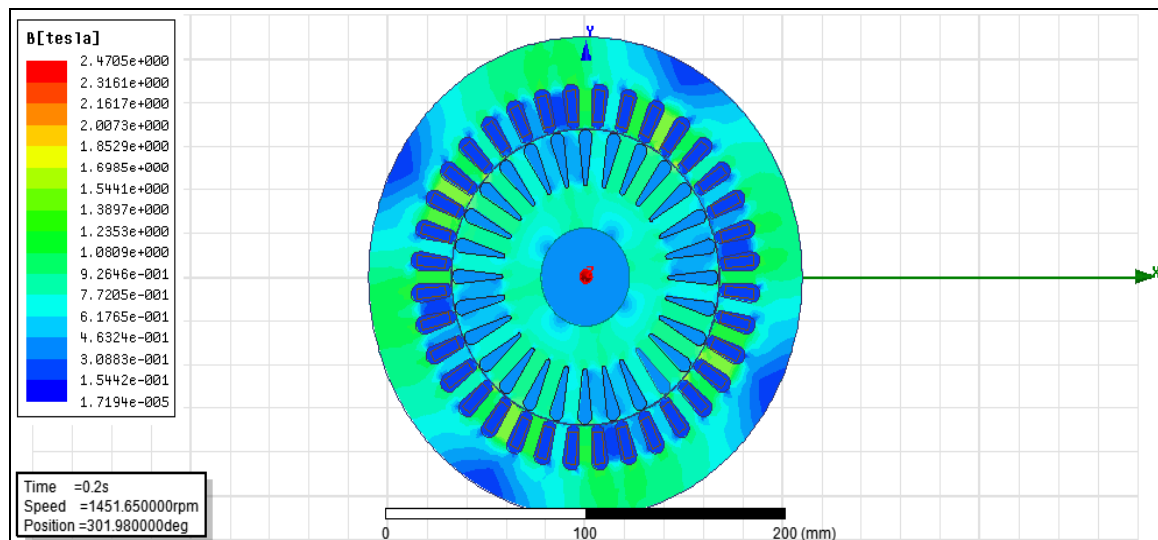


Fig. 10: (a) Flux Density Distribution with 27.58% Static Eccentricity.

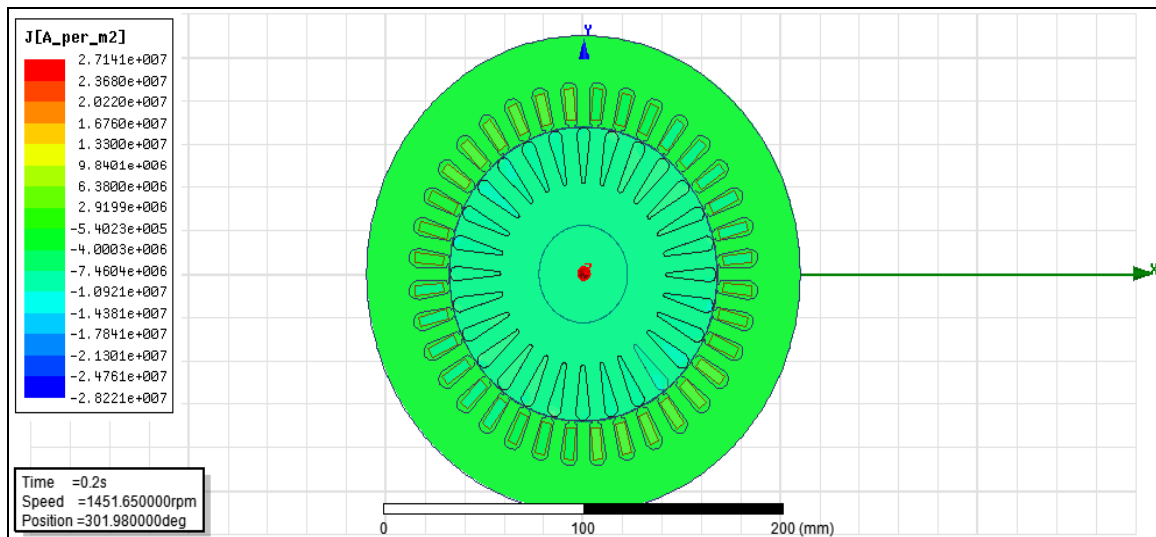


Fig. 10: (b) Current Density Distribution with 27.58% Static Eccentricity.

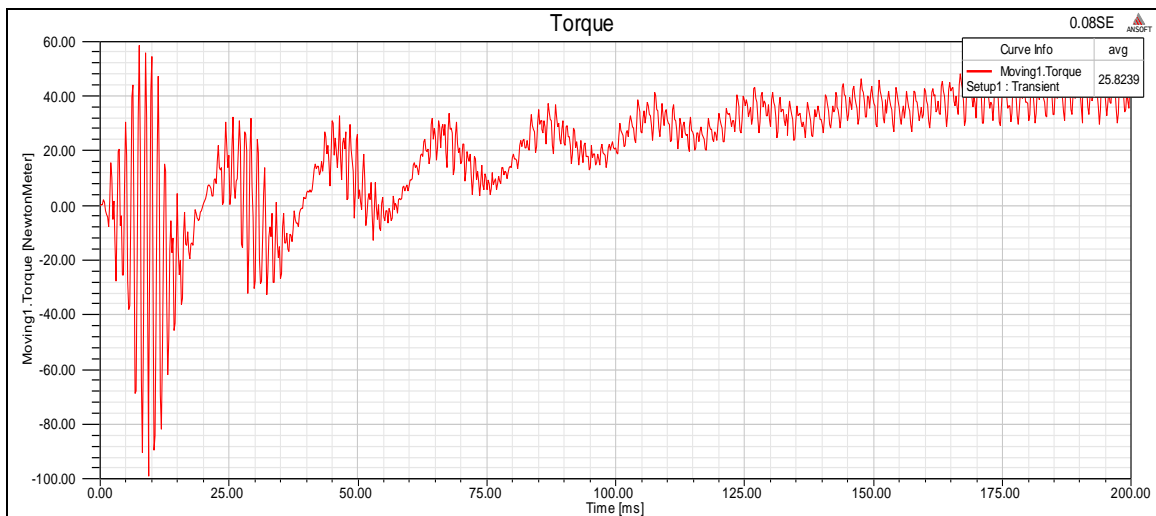


Fig. 10: (c) Torque Response of Induction Motor with 27.58% Static Eccentricity.

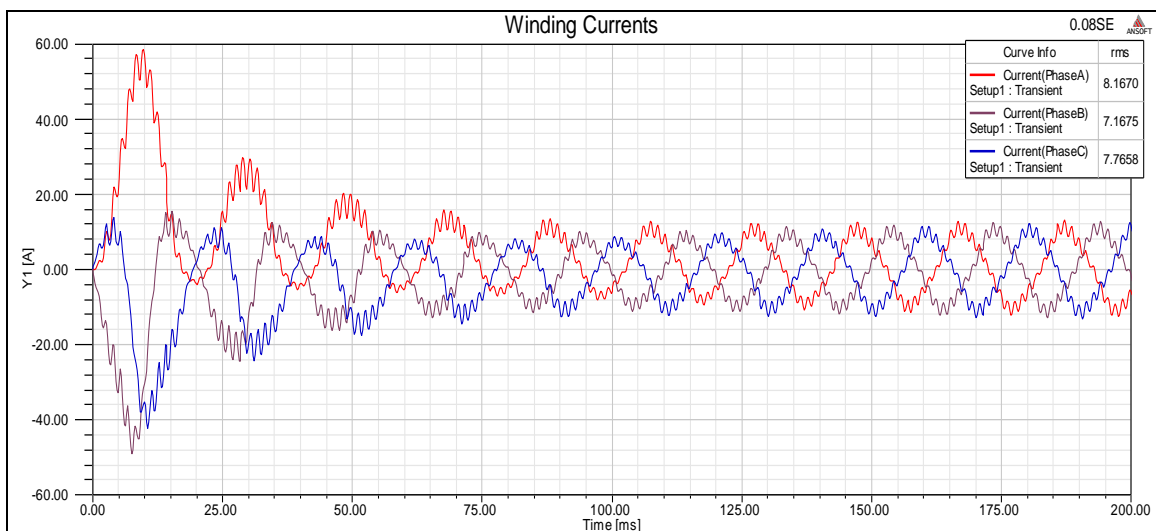


Fig. 10: (d) Current Response of Induction Motor with 27.58% Static Eccentricity.

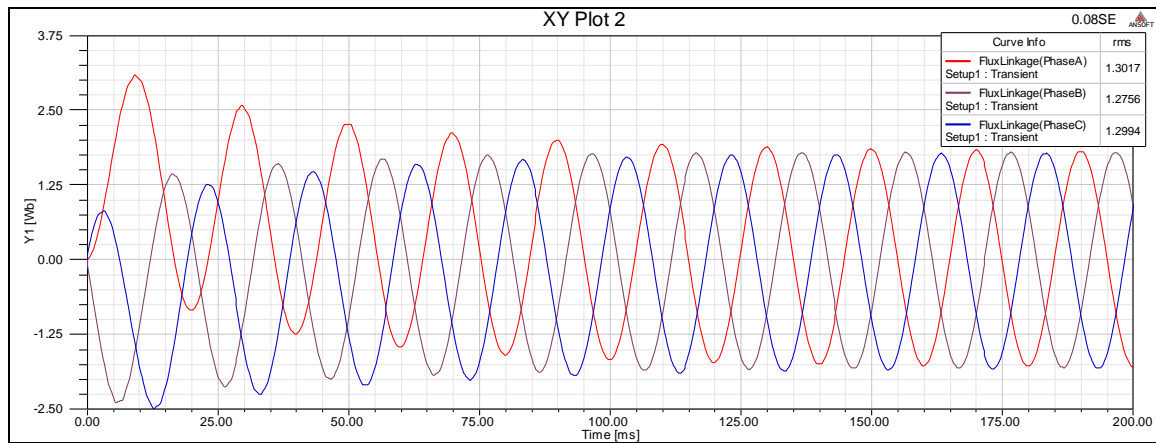


Fig. 10: (e) Flux linkage of Induction Motor with 27.58% Static Eccentricity.

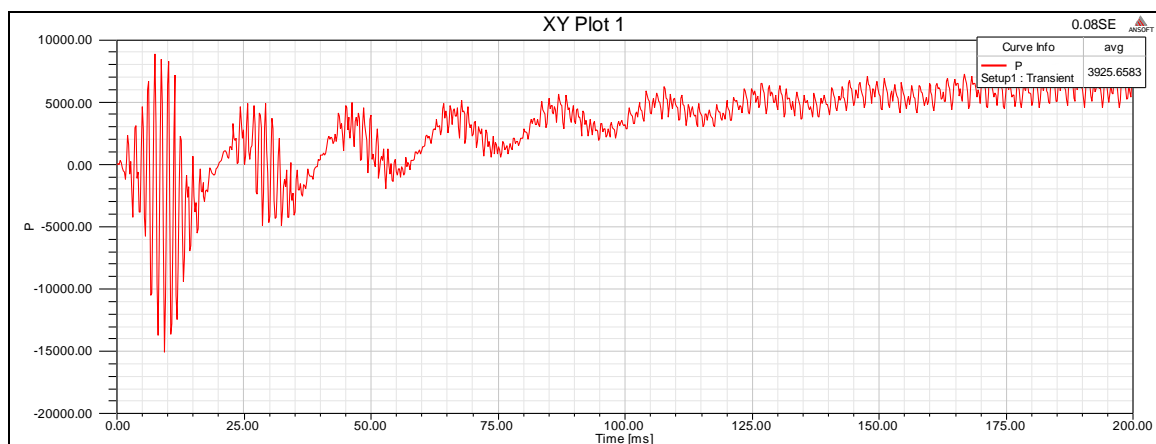


Fig. 10: (f) Output Power Response of Induction Motor with 27.58% Static Eccentricity.

Table 2: Comparison Table between Normal and Dynamic conditions with 34.48% and 27.58% variation.

Parameters	Normal Conditions	Faulty Conditions	
		34.48% Dynamic Eccentricity	27.58% Dynamic Eccentricity
Condition	Healthy	34.48% Dynamic Eccentricity	27.58% Dynamic Eccentricity
Magnetic torque Nm (Average)	25.8392	25.7804	25.7991
Stator current A (rms)	8.1644	8.1635	8.1649
Power W (Average)	3927.9849	3919.0514	3921.8917

Table 3: Comparison Table between Normal and Static conditions with 34.48% and 27.58% variation.

Parameters	Normal Conditions	Faulty Conditions	
		34.48% Static Eccentricity	27.58% Static Eccentricity
Condition	Healthy	34.48% Static Eccentricity	27.58% Static Eccentricity
Magnetic torque Nm (Average)	25.8392	25.8117	25.8239
Stator current A (rms)	8.1644	8.1660	8.1670
Power W (Average)	3927.9849	3923.7994	3925.6583

RESULTS AND CONCLUSION

The results of induction motor under various fault conditions are calculated and compared in the Tables 2 and 3, where Table 2 compares the induction motor under normal conditions

with the two different dynamic eccentricity situations and Table 3 compares the induction motor under normal conditions with the two different static eccentricity situations.

The study of the results shows that due to the non-uniform air gap, flux distortion will be occurred that cause distortion in torque, flux, voltage, and power in terms of fluctuations and mechanical vibrations.

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Cite this Article

Kalpana Sheokand, Neelam Turk. Detection of Eccentricity Fault for Induction Motor. *Trends in Electrical Engineering.* 2018; 8(2): 19–32p.