Scientific Journal of Impact Factor (SJIF): 4.14

e-ISSN (O): 2348-4470
p-ISSN (P): 2348-6406

International Journal of Advance Engineering and Research Development

Volume 3, Issue 6, June -2016

Analysis of Induction Motor with broken rotor bars Using Finite Element Method

AUTHOR: JANMEJAY VYAS[1]
GUIDED BY: N K SINGSIR(HOD)[2]

Abstract - *The paper presents the use of the two-dimensional finite element method for modelling the three-phase squirrel-cage induction motor by using circuit-field coupled method. In order to analyze the machine performances, the voltage source is considered. The flux 2D magnetic analysis software is used for calculating the magnetic field of an induction motor having a cage fault. The simulation results of transient and steady state are given, which verifies the reliability of this method. The experimental results prove that the proposed approach constitutes a useful tool for the study and diagnostics of induction motors.*

Keywords - *Induction motor, finite element, broken rotor bars, time stepping finite element (TSFE), diagnosis, faults.*

I. INTRODUCTION

Rotor faults of induction machines yield asymmetrical operation of this one, causing unbalanced currents, torque pulsation, increased losses and decreased average torque. The need for detection of rotor faults at an earlier stage, so that maintenance can be scheduled, has pushed the development of monitoring methods with increasing sensitivity and noise protection. For that, a model closer to reality considering faults conditions must be established. An analytical analysis method based on the rotating field theory and coupled circuit was used

[1]. In works, where the machine inductances are calculated and the machine performance is studied under faulty conditions, the Winding Function Approach (WFA), is used, where several assumptions and approximations of the actual machine layout are made, like the effects of stator teeth and slots, which are omitted in the calculations[2].

In this paper finite element technique is presented to diagnose partially broken rotor bar fault side by side the effect of non uniform air gap between stator and Rotor has been studied. To make the analysis simple here considered a 12 rotor pole motor's geometry with identical specifications and made similar model with two rotor bars broken, which has been achieved with software simulation without de-structuring the actual motor's design. The

specifications of the model have been mentioned in table 1.

Table I. Specifications of Induction Motor

Number of pole pairs	2
Number of stator slots	12
Number of rotor bars	12
Power	2500W
Current	11.5A
Voltage	180V
Frequency	50Hz
Speed	497 rpm
Length of motor	0.8m
Efficiency	78.6

II. FE Analysis of Induction Rotating

Machine for Rotor Mixed Faults

There are number of methods of analysis of induction motor that are used to predict the behaviour of the motor under eccentricity, broken or cracked rotor bars like: [3]

a) Magnetic Equivalent Circuit (MEC) method,
b) Finite Differences Method (FDM),
c) Winding Function Method (WFM) and
d) Finite Element Method (FEM).

The last method has shown best results in 2D/3D analysis [4]. Around 15% of fault in rotating machine happened due to broken rotor bar, which is lead due to small cracks, appeared at welding point after thermal stresses because of over loading. In present Analysis both healthy and unhealthy induction machine are modeled and with full load with same speed.

Table II: Comparitive Mesh statics

Items	Healthy motor	Unhealthy motor with Broken bar
Number of degrees of freedom	46133	46077
Number of mesh points	11512	11498
Triangular	22934	22906
Number of boundary elements	1983	1934
Number of vertex elements	204	200
Minimum element quality	0.763	0.759
Element area ratio	0.003	0.002

the comparative meshing statics mentioned in table II. which clearly shows the variations in no. of degree of freedom, no. of elements etc. for the Healthy Model and Unhealthy Model.
Fig. 1 shows a detail of the mesh used for simulation. The magnetic circuit of squirrel cage and the geometry are very close to the real machine.

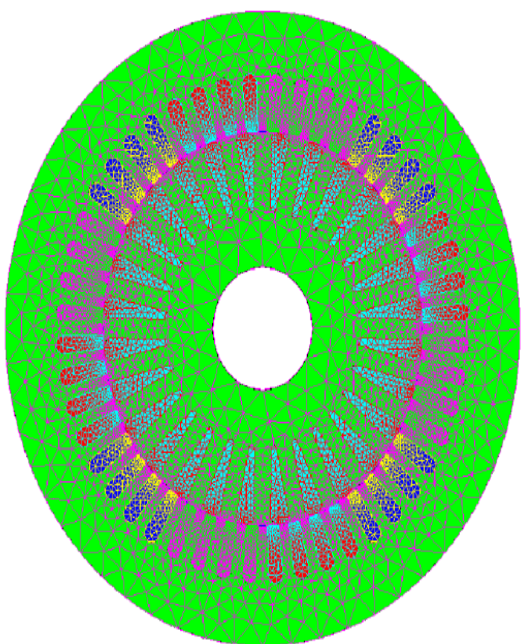


Fig. 1. Finite element meshes

III. SIMULATION RESULTS

In this paper, the induction motor is simulated under rated conditions. Fig. 2 shows the magnetic field distribution at steady state for healthy rotor. When the slip is small, the eddy current in the secondary conductor is small either. Therefore, the flux passes through the inside of rotor because of small effect of the field caused by eddy current. But above this, the results show that flux distribution is symmetrical in each pole.

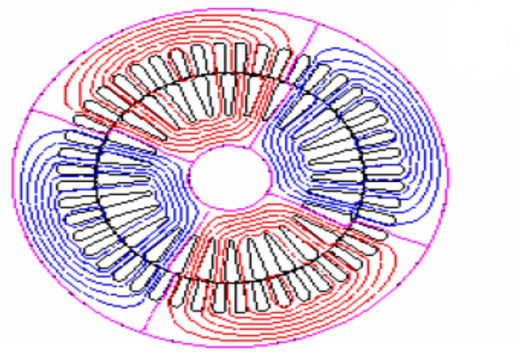


Fig. 2. Magnetic field distribution.

Fig. 3 shows the magnetic flux distribution for healthy rotor and with one broken bar at the transient state. When the slip is large, the eddy current shows a large value. This high value of slip is necessary to illustrate the effects of the broken bars on the field. The concentration of magnetic flux is observed around the broken bar and creates asymmetric magnetic flux distribution. One can notice that the region around the broken bar of the rotor has a higher degree of saturation in comparison to the same region with no broken bars . This is due to the fact that in the broken bar region there is no localized conductor demagnetization effect since these bars carry no currents .

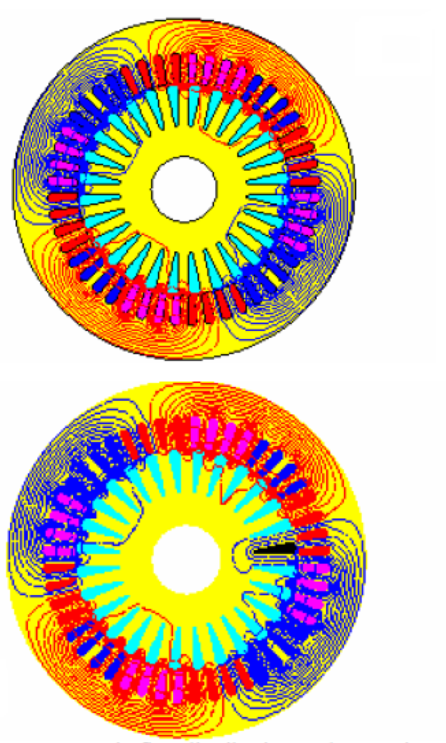
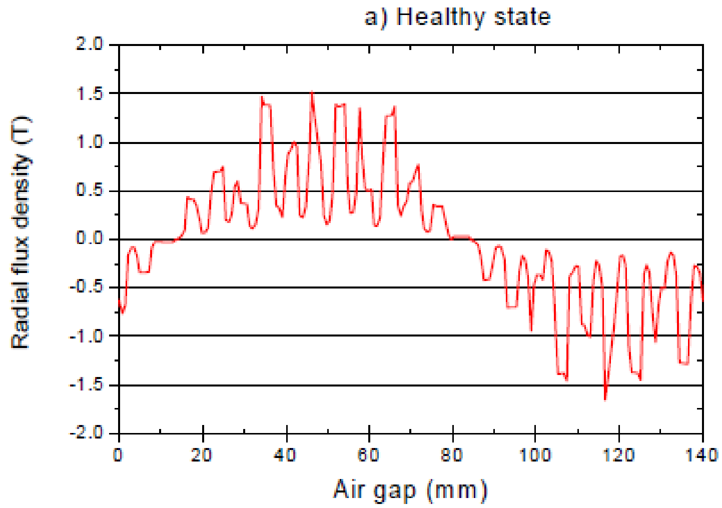


Fig. 3. Magnetic flux distribution at the transient state
Top: Healthy rotor, Bottom: One broken bar

One can notice that the region around the broken bar of the rotor has a higher degree of saturation in comparison to the same region with no broken bars . This is due to the fact that in the broken bar region there is no localized onductor demagnetization effect since these bars carry no currents .

Fig. 4 shows the waveform of the air gap flux density along a circular contour in the air-gap. The flux densities have a symmetrical distribution in healthy state. The perturbation in the magnetic field produced by 5 broken bars results in a nonsymmetrical field .



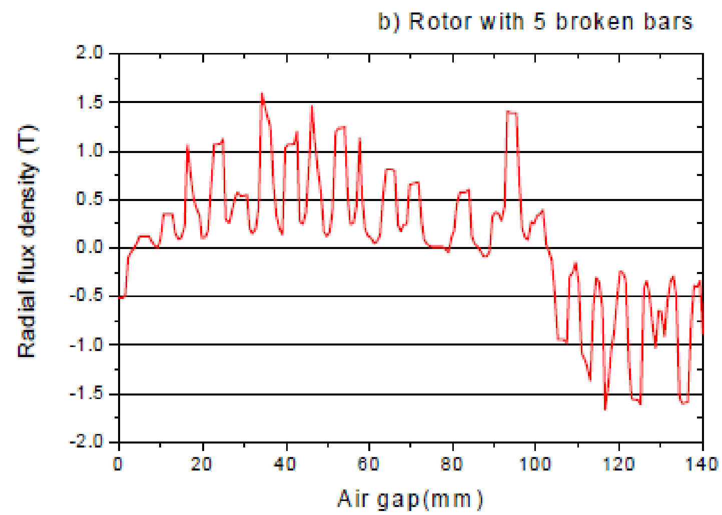


Fig. 4. Waveform of the Air gap flux density

V. SPECTRUM ANALYSIS OF STATOR CURRENT

An induction machine rotor asymmetry introduced by
broken bars produces spectrum lines of stator current at frequencies:

$$f_{bb1} = f_s(1 \pm 2ks)$$

Where *fs* is the electrical supply frequency, s is the slip, k □1,2,3,..., respectively.

In Fig. 9, the spectra of the simulated stator current with healthy rotor and with one broken bars are presented. In case of broken rotor bar, the rotor is electrically asymmetric and the backward rotating field is created. The current spectrum reveals sidebands expected around the supply frequency given by (1)].

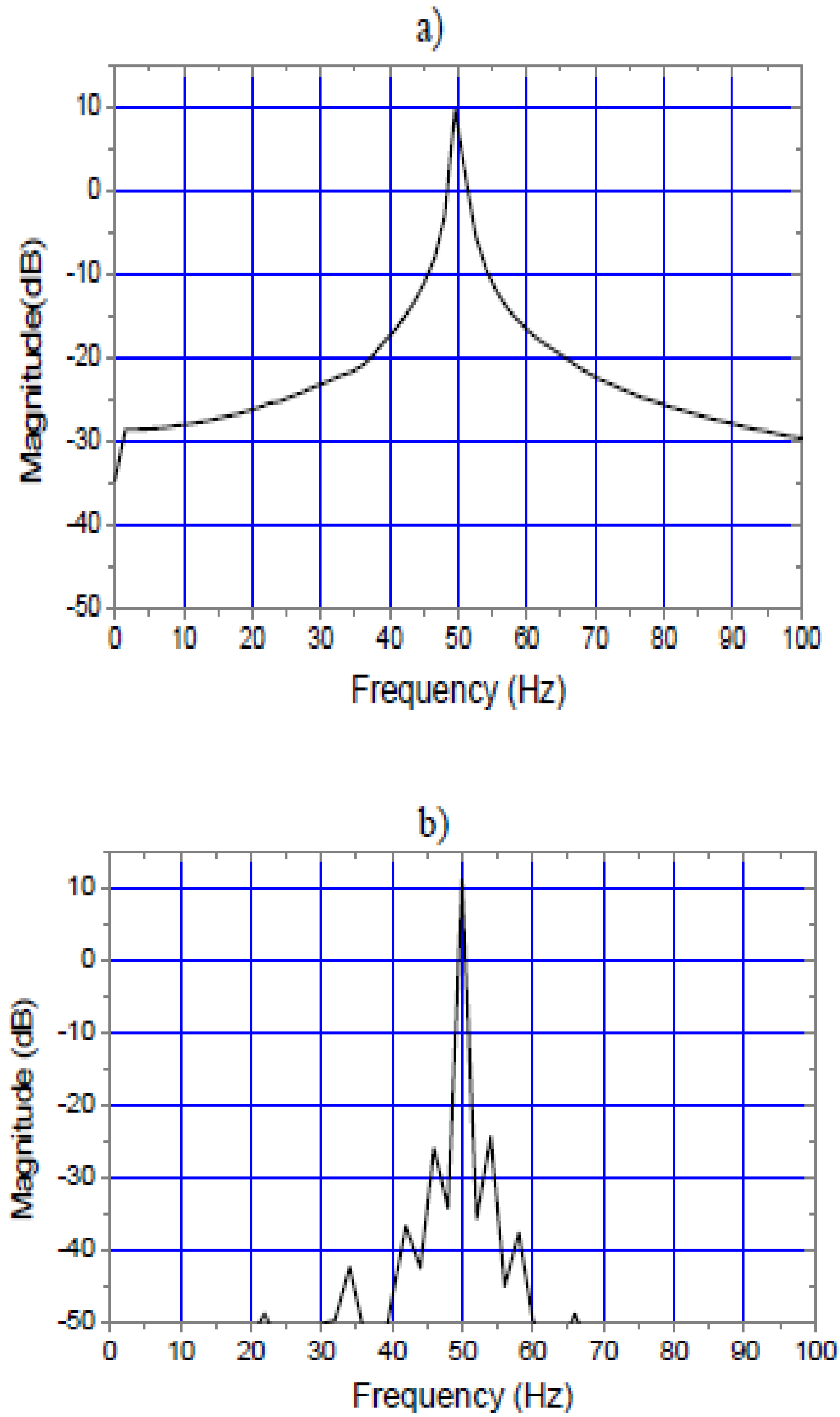


Fig. 9. Simulated current spectrum
a) Healthy rotor
b) Rotor with 1 broken bar

Fig.5. Stator current

In order to have a better understanding of rotor broken bar, it may be necessary to examine the higher frequency components of the frequency spectra. When we took into account the space harmonics, additional frequency appear at frequencies given by:

$$f_{bb2} = f_s\left\{\frac{k}{p}(1-s) \pm s\right\}$$

Where, p is the number of pole pairs and k/p = 1, 3, 5, 7….
The spectra of the stator current of a loaded machine when it runs in healthy conditions are shown in Fig. 10. It is obvious that besides the supply frequency component, higher frequency components exist around the principal slot Harmonics as was predicted. Some frequency components (250Hz, 350Hz, etc.) exist which are a result of the saturation of magnetic material. Due to the configuration of three phase windings, harmonic orders that exist are: k/p = 1, 5, 7, 11…
In this simulation, magnetic saturation patterns cause the 3rd harmonic and it's multiple to appear as non-zero components in the spectra of the phase currents. The spectra of the stator current of a loaded machine when it runs in faulty conditions are shown in Fig. 11.

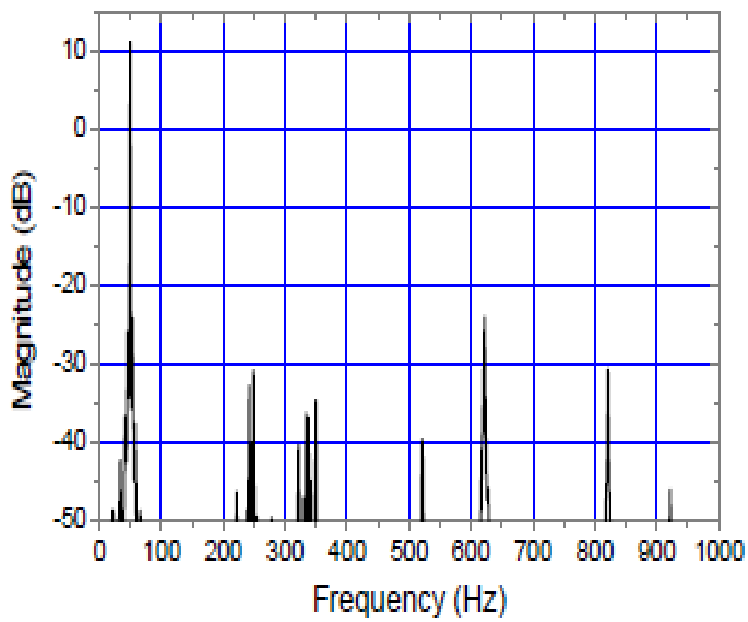


Fig.11. Simulated current spectrum with one broken bar

The stator current frequency described by (1) and (2) can be detected over the observation bandwidth between 0 Hz and 1000 Hz. The current spectrum reveals sidebands expected around the supply frequency. Even for a motor in a healthy state, there are always frequency components but of low amplitudes, this is due to the natural asymmetry of the motor, and on the other hand from the power supply (distortion in the power supply voltage waveform).

VI. CONCLUSION

This paper presents the circuit coupled finite element method used to modeling the Three-Phase Squirrel Cage Induction Motor. For this purpose, the time-stepping finite element method (TSFE) was proposed. The determination of magnetic flux density waveform, magnetic flux distribution was obtained. The perturbation in the air-gap magnetic field produced by broken bars results in a non-symetrical field. The stator current waveform obtained with simulation was in good agreement with the experimental results. The simulation waveforms of speed and torque transients of induction motor during start-up confirm the known experimental results. As envisaged during simulation, the presence of harmonics in current spectra at low and high frequency confirm the experimental results, proving that the proposed approach constitutes a useful tool for the study and diagnostics of induction motors. It will be mentioned that this approach is limited only to the evaluation of the component frequencies induced by the broken bars fault.

References

[1] Manpreet Singh Manna, Sanjay Marwaha & Anupma Marwaha, "Finite Element Study of Air-gap Eccentricity And rotor bar Faults in electrical Rotating induction Machine" Int. J. of Advancements in Computer Science and Information Technology, ISSN 2249-6580, Vol. 01, No. 1, pp 50-56, 2011.

[2] Manpreet Singh Manna, Sanjay Marwaha & Anupma Marwaha, "3D FEM Analysis of EM Force on End Winding Strucure for Electrical Rotating Machines" in 4th IASTED International Conference on Circuits, Signals and Systems (CSS 2006) at *San Francisco, California, USA,* 2006.

[3] A.A. Abdel-Razek, J.L. Coulomb, M. Feliachi, J.C. Sabonnadiere, "Conception of an Air-Gap Element for the Dynamic Analysis of Electromagnetic Field in Electric Machines" in IEEE Trans. on MAGNETICS, Vol. MAG-18, No. 2, pp.*655,* 1982.

[4] Manpreet Singh Manna, Sanjay Marwaha & Anupma Marwaha, "Finite Element Analysis for Performance Prediction of Induction Motor with Broken Rotor Bars" in IASTED Technology and Management Conference (AsiaPES-2010) International Conference on Power and Energy Systems at *Phuket, Thailand*, 2010.

[5] Mehmet AKAR & İlyas ÇANKAYA "Diagnosis of Static Eccentricity Fault in Permanent Magnet Synchronous Motor by On- Line Monitoring of Motor current and Voltage" , ISTANBUL UNIVERSITY – Journal o Electrical & Electronics Engineering, Vol. No: 9., 2009.

[6] Mehmet Akar, Sezai Taskin, Serhat S¸ Eker, ˙Ilyas C¸ Ankaya, "Detection of Static Eccentricity for Permanent Magnet. Synchronous Motors using the Coherence Analysis" , J Electrical Engineering & Comp Science, Vol.18, No.6, 2010.

