Journal of Engineering and Development, Vol. 17, No.3, August 2013, ISSN 1813- 7822

Analysis AND Monitoring Characteristic Performance OF Squirrel- Cage Induction Motor WITH Broken Bars

Dr. Khaleel J. Hammadi
Department of Electronic Technology, Institute of technology, 2012
Baghdad-Iraq, E-mail: Khal.dr59@yahoo.com

Salem Hachem Farhan
Department of Electronic Technology, Institute of technology, 2012
Baghdad-Iraq, E-mail: saleimhachem@yahoo.com

Maher Ibrahim Gamai
Department of Electronic Technology, Institute of technology, 2012
Baghdad-Iraq, E-mail: maheralwardy@yahoo.com

Abstract

This paper develops the foundations of a technique for diagnosis and characterization of effects of broken bars in squirrel-cage induction motors based on the time-stepping coupled finite-element approach. These studies are performed by using the model to compute healthy case, with two adjacent broken bars fault performance data, which contains time variations of torque with broken bars and the distribution of magnetic field. From this data, the faulty signatures are extracted. Furthermore, this method, which could help to develop diagnostics of broken bars and performance evaluation of induction motors, has great potential in future applications.

Key words: Squirrel-cage induction motor, Broken rotor bars, faults diagnosis, finite element (FE)

تحليل ومراقبة الأداء لخواص المحرك الحثي ذو القفص السنجابي في حالة القضبان المكسورة

د.خليل جديع حمادي
معهد التكنولوجيا
قسم التقنيات الالكترونية

سليم حاجم فرحان
معهد التكنولوجيا
قسم التقنيات الالكترونية

ماهر إبراهيم جمعة
معهد التكنولوجيا
قسم التقنيات الالكترونية

الخلاصة :

يقدم هذا البحث تطور الأسس التقنية لتشخيص وتوصيف آثار الكسر في قضبان المحركات الحثية ذو قفص السنجاب بالاستناد إلى طريقة زمن الخطوة للعناصرالمحددة. يتم تنفيذ هذه الدراسات باستخدام نموذج لحساب الحالة الصحيةلمحرك، واثنين من ببيانات الأداء لمحرك ذوالقضبان المجاورة المكسورة ، الذي يحتوي على محور الزمن مع محورعزم الدوران مع القضبان المكسورة وتوزيع المجال المغناطيسي. من هذه البيانات، يتم استخراج ومعرفة اماكن الكسر. وعلاوة على ذلك، هذه الطريقة التي يمكن أن تساعد على تطوير التشخيص للقضبان المكسورة وتقييم اداء المحركات الحثية، ولهذ البحث امكانات كبيرة في التطبيقات المستقبلية.

1. Introduction:-

Motors are commonly used in a variety of industrial applications, and some induction motors are key elements in assuring the continuity of the process and production chains of many industries. However, rotor bars breaking in the motor occurs frequently. Rotor failures are caused by inadequate casting or a combination of various stresses which act on the rotor. A sudden motor failure may reduce productivity and may be catastrophic in an industrial system. Hence, early detection of broken bars would help to avoid catastrophic failures and reduce repair costs. The squirrel-cage induction motor which was used in this paper is a motor with 3-phase, 4 pole, and 28bars. The distribution of magnetic field, Torque, and speed vs time, waveform magnetic flux density in the air gap [1- 4], and so on were calculated by using the finite element (**FE**) method for the healthy case and faults constituting two broken rotor bars.

Table (1) . Squirrel-cage induction motor parameters

Number of poles	**4**
Number of phases	**3**
Outer diameter of stator	**162.5mm**
Inner diameter of stator	**69.3mm**
Air gap length	**1mm**
Axial length	**50mm**
Number of stator slots	**36**
Number of rotor bars	**28**
Rated voltage (V) rms	**400**
Rated frequency (Hz)	**50**
Number of stator turns/phase	**180**

2. FEM model of the induction motor

In recent years the Finite Element Method (FEM) becomes widely used in the design and analysis of electric machines and of her electromagnetic devices. So far a lot of program packages for computation of magnetic field, especially for two dimensional (2D) analysis have been developed [2]. This method it is based on Maxwell's equations for magnetic and electric **field** [3]**:**

$$\nabla \times \bar{H} = \bar{J} \text{ and } \quad \nabla \times \bar{E} = \frac{dB}{dt} \qquad \textbf{(1)}$$

Where $\bar{H}$ is the magnetic field strength [A/m], $\bar{E}$ is the electric field strength [V/m], $\bar{J}$ is the electric current density [A/m2], $\bar{B}$ is the magnetic flux density [T]. Moreover, the electric and magnetic field quantities are related with the material properties expressed by the following relations:

$$J = \sigma . E \text{ and } \quad B = \mu . H \qquad \textbf{(2)}$$

Where σ is the electrical conductivity [S/m], μ is the magnetic permeability [H/m]. Based on these equations FEM based programs compute the magnetic field distribution of any electrical machine.

In the case of the 2D analysis the computations are performed for a transversal plane to the axes of the machine.

The use of simulation tools helps the researchers to emphasize the effects caused by faults in an electrical machine and to develop efficient fault detection methods. Using FEM analysis the changes in electric,

magnetic and mechanic behavior of the machine due to any fault can be easily observed without the need of destroying a machine, or experimenting in laboratories machines with different fault types. The main idea was to understand the electric, magnetic and mechanical behavior of the machine in the healthy state and under fault condition.

3. Modeling of broken bars

When the rotor bar are broken the current of that bar equal to zero as shown in **Figure.(1).**

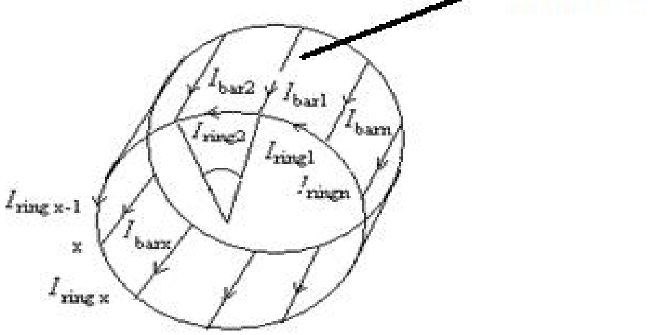

Fig. (1) : Distribution form of rotor bars current for faulty motor

No current of the broken bar means a higher current in its adjacent bars which may saturate those rotor teeth that are close to the adjacent bars. On the other hand this causes an asymmetrical distribution of the magnetic flux in the air gap. The reason for asymmetry of the magnetic flux distribution is injection of the harmonics, caused by the broken bar fault to the stator current.

$$I_{ring2} = I_{bar1} + I_{ring1} \quad (3)$$

$$I_{ringx} = I_{barx} + I_{ringx-1} \quad (4)$$

When the rotor bar are broken the current of that bar is assumed equal to zero, that mean $I_{bar2} = 0$ next the value of current become;

$$I_{ring2} = 0 + I_{ring1} = 2I_{rr} \quad (5)$$

$$2I_{rr} = I_{bar,n} + I_{ringn} \quad (6)$$

Where I_{rr} = Current of rings between broken bar

4. Simulation Results

In recent years FEM has become widely used in the design and analysis of electric machines and other electromagnetic devices. So far, a lot of program packages for computation of magnetic field, especially for two dimensional analyses have been developed.

4.1 Stator Current Waveform

The simulated stator current waveforms by using FEM opera-2d for the case of broken rotor bars is given in **Figure 2.** One can notice that the amplitude of stator current changes significantly compared to that in the healthy cage. The reason is that the broken rotor bars causes asymmetry of flux distribution which leads to higher harmonics in the faulty motor.

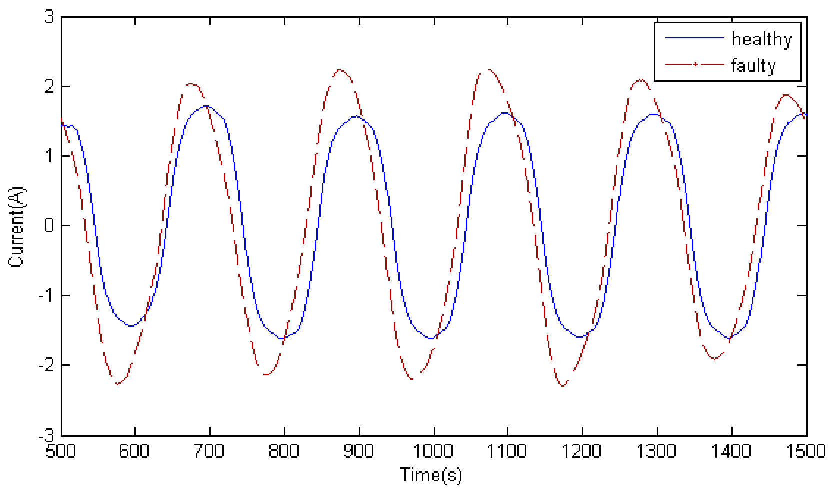

Fig. (2): stator current waveform in healthy and faulty state

4.2 Flux Density Waveform

Broken rotor bars produce certain frequencies in the flux waveform and the rotating flux waves can induce the currents with the same frequency in the stator current. Therefore by increasing the number of broken rotor bars in the motor, a higher asymmetry of the flux distribution occurs as shown in **Figure 3.** It can be easily observed that in the case of the faulty motor the magnetic flux density *B* in the air gap is more unbalanced and it has a pronounced fluctuation, due to the backward rotating magnetic field produced due to rotor faults. This is rotating at the slip speed, $n_2 = n_1(2s - 1)$, with respect to the **stator** [7]**.**

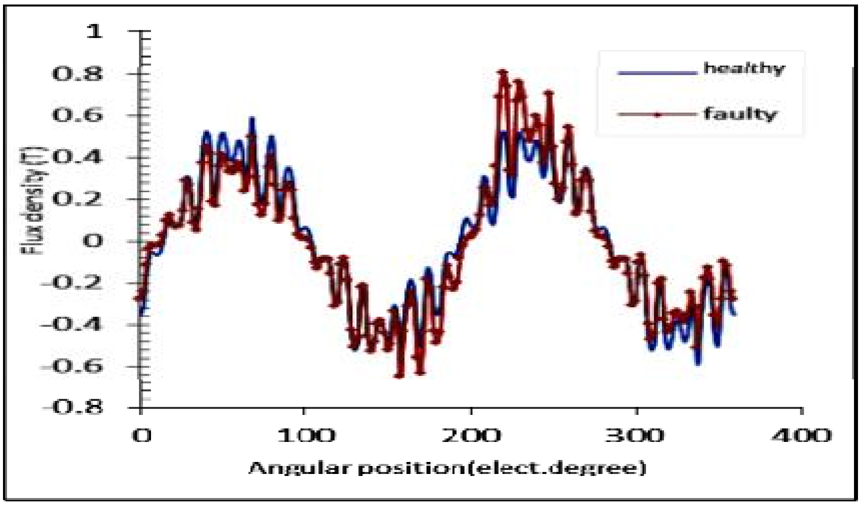

Fig. (3): Air gap flux density in the healthy state and faulty state with broken bar

5. Magnetic Field Distribution

The magnetic field distribution is symmetrical in case of the healthy Squirrel-cage induction machine **(Figure. (4.a**). When the rotor faults occur the magnetic field becomes asymmetrical due to the lack of currents in the broken bars. This leads to local saturation of the rotor and the stator core near the broken bars**(Figure.(4.b).**

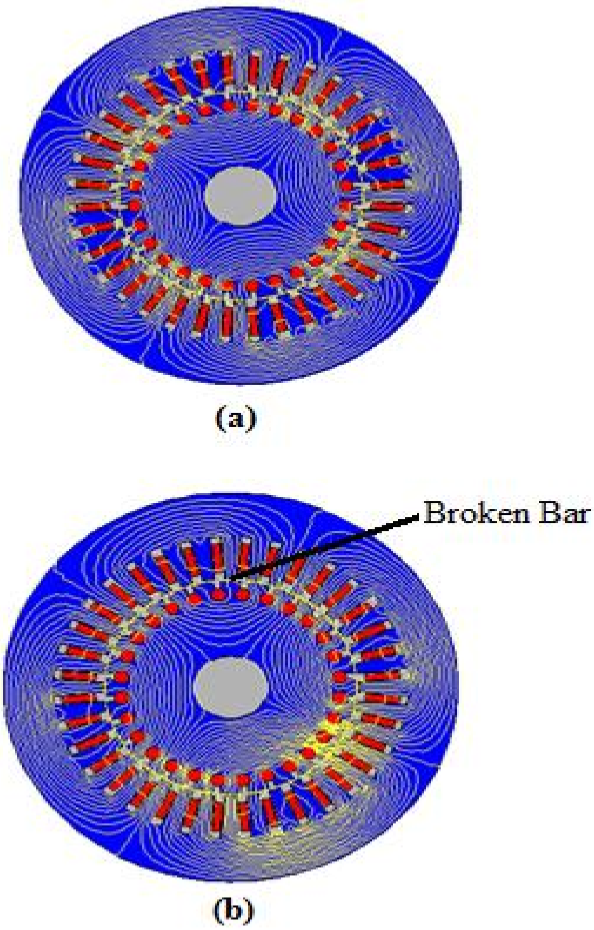

Fig. (4): Magnetic flux plots in case the healthy motor (a) and with having broken rotor bars (b)

5.1 Torque Ripple

The magnetic torque ripples are also increased in case of the faulty induction motor than in case of the motor without any rotor fault as shown in **Figure 5.** The time variations of torque for a healthy and faulty induction motor with two broken bars are present. Comparison of healthy and faulty state indicates that the rotor broken bars increases the oscillation of the developed torque. One can easily notice that in the case of the motor having broken rotor bars the torque has the highest **value [8].**

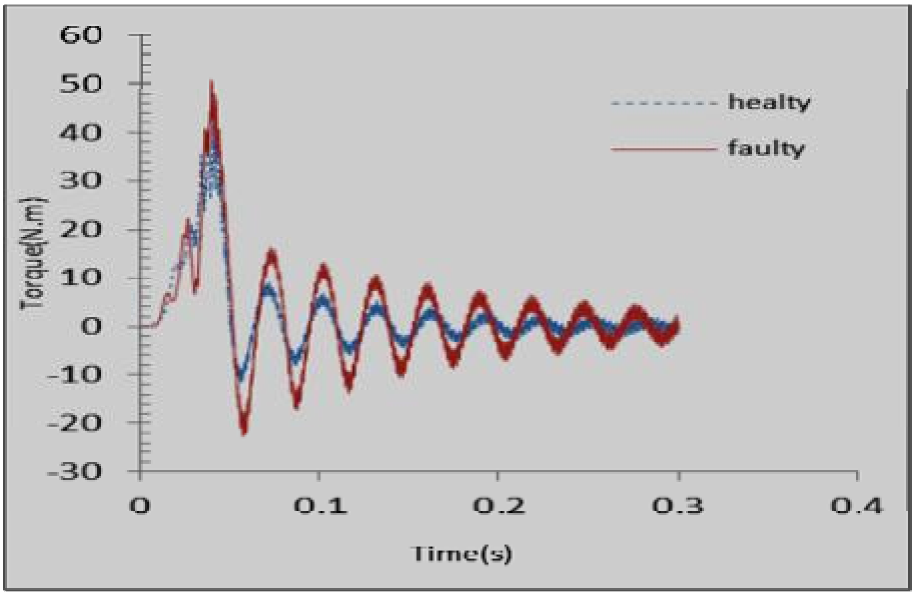

Fig. (5): Time variations of torque induction motor in healthy state and faulty state

6. Conclusions

Finite element method was used to determine the magnetic field distribution both in healthy induction machine and the machine having two broken rotor bars. The presented FEM analysis is one effective and inexpensive method for studying the influence of rotor faults on behavior of three phase squirrel-cage induction machines. This method also allows studying the effect of rotor faults on stator line currents, applicable on developing effective fault diagnostic tools. Once again it has been proved that the bars next to broken ones are the most exposed to future damage, due to the very high value bar currents.

References

1. **SZABÓ, L., DOBAI, J.B., BIRÓ, K.Á.: Rotor faults detection in squirrel-cage induction motors by current signature analysis, Proceedings of 2004 IEEE-TTTC International Conference on Automation, Quality and Testing, Robotics, Cluj (Romania), 2004, pp 353-358.**
2. **A. Bentounsi and A. Nicolas, "On line diagnosis of defaults on squirrel cage motor using FEM," *IEEE Trans. Magn.*, vol. 34, no. 3,pp. 3511–3514, May 1998.**
3. **STURGESS, J.P., PRESTON, T.W.: Damper cage design using the finite-element method. 6thInternational Conference on Electrical Machines and Drives, pp 457-462.**

4. **FIŠER, R., MAKUC, D., AMBROŽIČ, V.: Evaluation of the induction motor cage fault stage using finite element method. Record of IEEE SDEMPED'2001, The 2001 IEEE International Symposium on Diagnostics for Electrical Machines, Power Electronics and Drives, Grado (Italy), pp. 627-631.**
5. **PÖYHÖNEN, S., NEGREA, M., JOVER, P., ARKKIO, A., HYÖTYNIEMI, H.: Numerical magnetic field analysis and signal processing for fault diagnostics of electrical machines. The International Journal for Computation and Mathematics in Electrical and Electronic Engineering vol. 22, no. 4, pp. 969-981, 2003.**
6. **ZHOU, P., FU, W. N., LIN, D., STANTON, S., CSENDES, Z. J. and LONGYA Xu: NumericalModeling of Electrical Machines and Its Application. 37th IAS, Industry Applications Conference, vol. 3, 2002, pp. 1936-1942.**
7. **SZABÓ, L., DOBAI, J.B., BIRÓ, K.Á.: Virtual Instruments for detecting rotor faults in inductionmotors, Advan-ces in Electrical and Electronic Engineering, no. 2, vol. 3 (2004), Žilina (Slovakia),pp. 119-122.**
8. **FIŠER, R., AMBROŽIČ, V., LESKOVEC, R.: Modeling of dynamic and steady-state performance of induction motor having rotor asymmetry. . Record of IEEE SDEMPED'2001, The 2001 IEEE International Symposium on Diagnostics for Electrical Machines, Power Electronics and Drives, Grado (Italy), pp. 127-132.**