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INFLUENCE OF THE ROTOR CAGE FAULTS IN AN INDUCTION MOTOR ON ITS RUNNING. EXPERIMENTAL RESULTS

The paper deals with investigation of the rotor cage faults in an induction motor. Induction motor 90L-4 type with rated power 1.5 kW and synchronous speed 1500 rpm with various faulted rotors was examined. Influence of the rotor cage fault on the temperature rise of the motor rotor and stator is presented. Motor torque for rated load torque is analysed.

1. INTRODUCTION

Induction motors are widely used in domestic and industry appliances. Almost 90 percentages of industrial motors are induction motors [1]. Induction motors are favoured due to their ruggedness and simplicity. The most rugged and simplest type of induction motor is a squirrel-cage motor. Its main advantages are:

– low cost,
– robustness,
– extreme reliability,
– low-maintenance,
– extreme life expectancy.

Induction motors are especially subjected to faults during their starting. In that state induction motor draws much higher current (5–10 times higher than rated current) what causes extreme power loss in the motor windings and extreme electrodynamic forces with frequency two times higher than power net frequency [2]. In squirrel-cage motors in the solid rotor bars except mechanical stresses due to electrodynamic forces there are

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another extreme stresses due to non-uniform temperature distribution on the rotor bars surface and due to centrifugal force caused by the rotational motion of the whole rotor. In case of the die-cast rotor cage there can occur an additional fault – during rotor cage die-casting air bubbles may remain in the rotor bar material volume. It can cause local overheat during motor running and fault of the rotor cage. Thermal stresses cause mechanical deformation of the rotor bars and end rings. Initial symptom of the rotor cage faults is a crack between end ring and rotor bars. Crack of the one or few rotor bars does not influence significantly on the motor properties but they cause local overheat and can extend the rotor cage fault [3]. Extended rotor cage fault makes worse significantly the motor properties and can damage the stator winding due to stator winding insulation overheat or devastation due to warped or slipped elements of the faulted rotor winding.

2. INVESTIGATED MOTOR

Induction motor 90L-4 type with P_n = 1.5 kW, U_n = 400 V, I_n = 3.5 A, f_n = 50 Hz, n_n = 1370 rpm, η_n = 79%, PF_n = 0.78 was investigated. Number of the stator slots equals 36 and number of the rotor slots equals 28. Eight motor rotors with various numbers of the damaged bars were applied. Rotor bars were damaged by cutting out connection between squirrel-cage bars and end ring. Cross-sections of the motor with eight rotors with various numbers of the damaged bars are shown in Fig. 1.

3. EXPERIMENTAL RESULTS

The motor with various number of the faulted rotor bars was supplied by the nominal voltage and loaded by the nominal load torque. The results of the temperature rise for the investigated motor stator and rotor are shown in Figs. 2, 3 and Tab. 1. Temperature distributions on the rotor surface for various number of the damaged rotor bars are presented in Fig. 4.

The obtained investigation results show clearly that rotor cage fault has significant influence on the temperature rise of the stator and rotor. Rotor or stator temperature rise is proportional to the number of the damaged rotor bars. One damaged rotor bars has no influence on the motor temperature rise but each consecutive damaged rotor bar increases the motor temperature rise significantly. Moreover, temperature distribution on the induction motor rotor with damaged rotor bars is strongly non-uniform. The rotor surface area above the damaged rotor bars is distinctly colder than area above healthy rotor bars due to no current flowing through the cracked rotor bars.

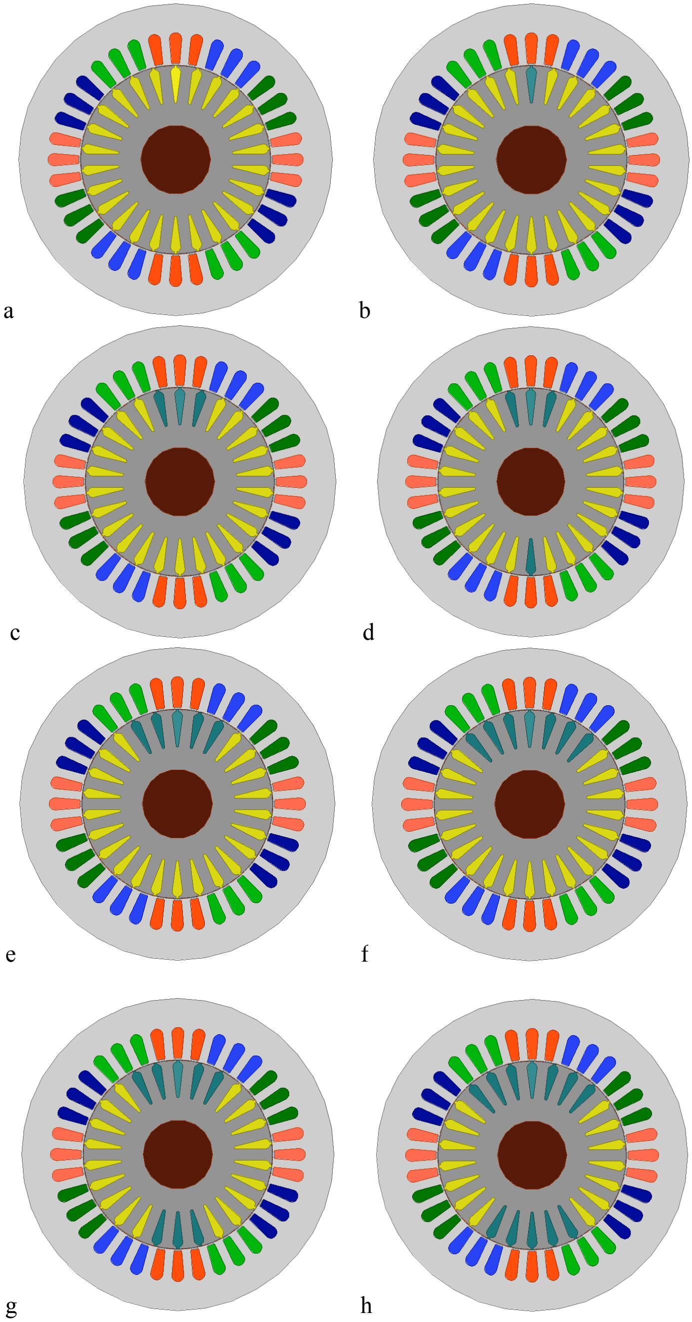


Fig. 1. Distribution of the damaged rotor bars in the investigated motor
(No. of the damaged bars: a – 0; b – 1; c – 3; d – 3+1; e – 5; f – 7; g – 5 + 3; h – 7 + 5)

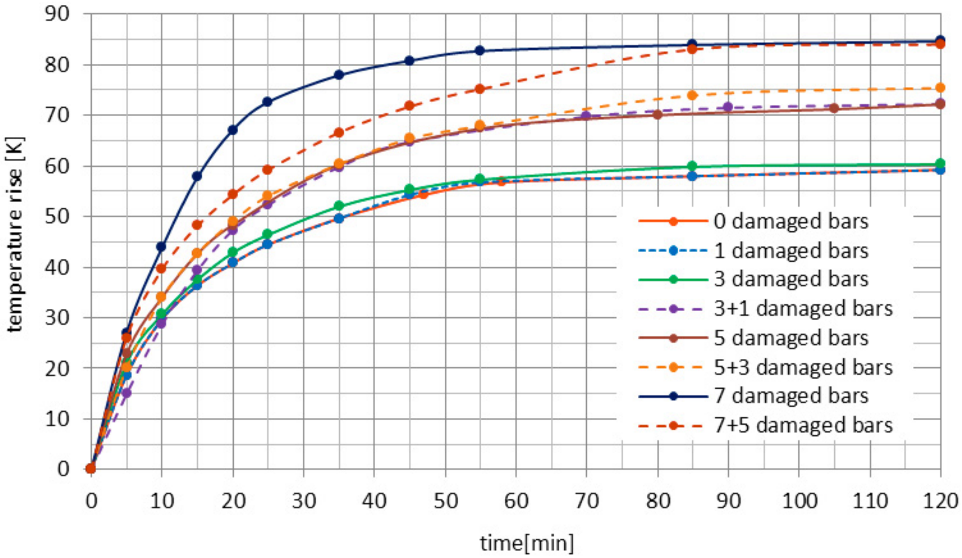


Fig. 2. Stator temperature rise for various number of the damaged rotor bars

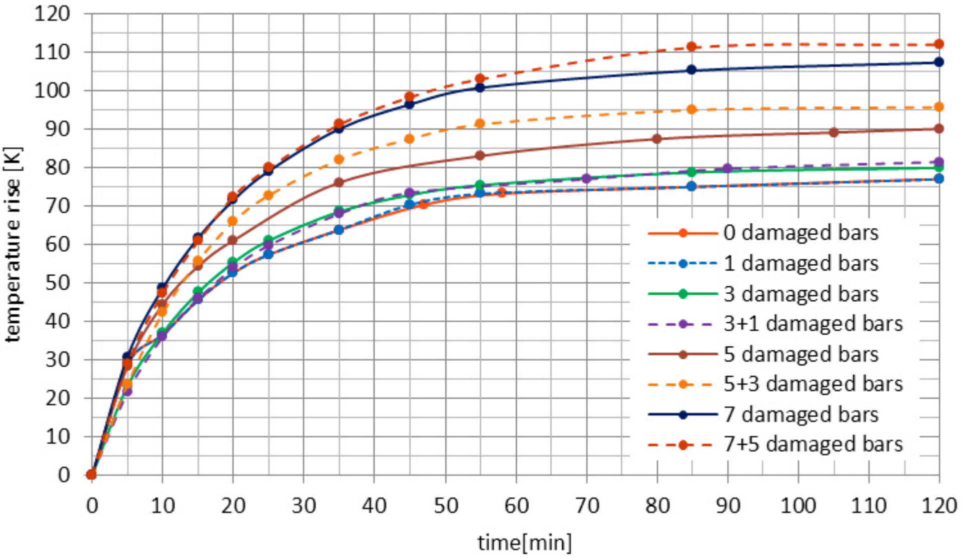
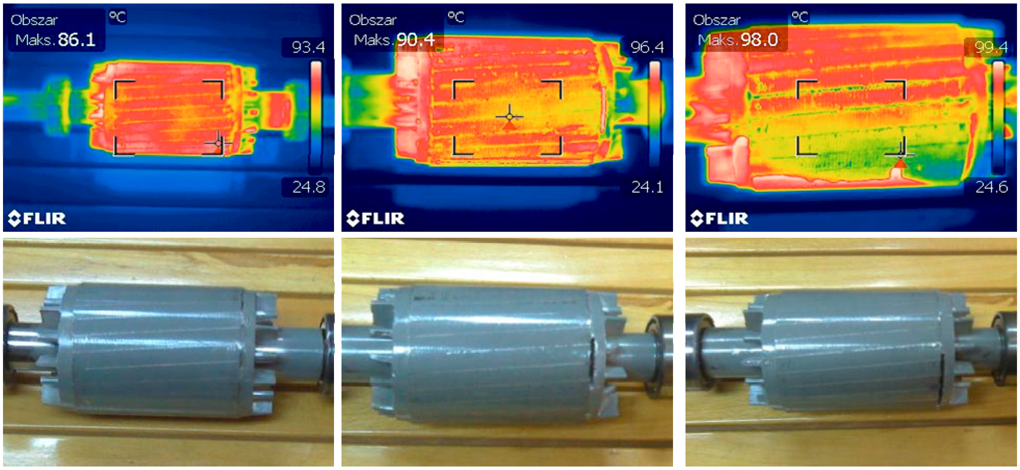


Fig. 3. Rotor temperature rise for various number of the damaged rotor bars

Table 1. Motor temperature rise for various number of the damaged rotor bars

No. of damaged bars	Temperature rise [K]	
	rotor	stator
0	72	59
1	72	59
3	80	60
3 + 1	81	72
5	90	72
5 + 3	96	75
7	107	84
7 + 5	112	84



a b c

Fig. 4. Temperature distribution on the rotor surface for various number of the damaged rotor bars (No. of the damaged bars: a – 0; b – 3; c – 5)

The motor torque in time domain during starting for rated load torque and for various number of the damaged rotor bars is presented in Fig. 5. Torque pulsation for steady state of the rated motor load was calculated according to the formula (1):

$$T_{\text{pulsation}} = \frac{T_{\max} - T_{\min}}{T_n} \cdot 100\% \,. \tag{1}$$

The obtained results of the motor torque pulsation, speed and slip for various number of the damaged rotor bars are presented in Tab. 2.

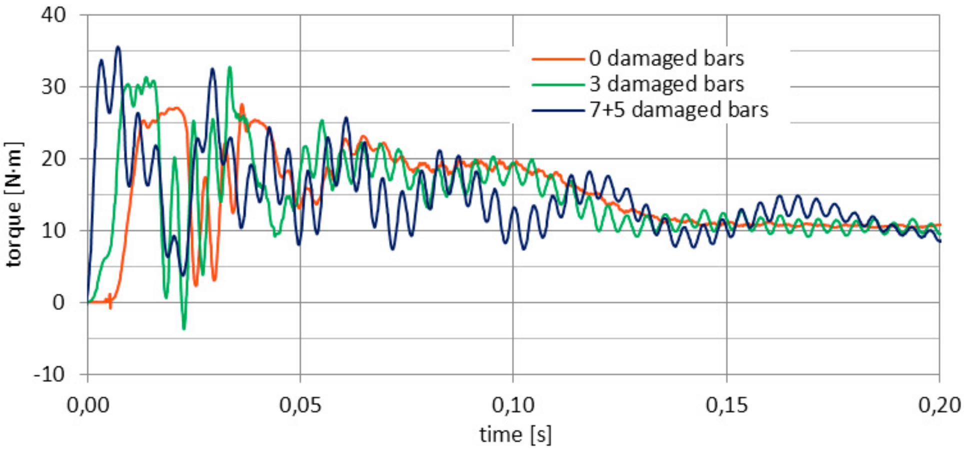


Fig. 8. Torque in time domain during motor starting for rated load torque

Table 2. Motor torque pulsation, speed and slip for various number of the damaged rotor bars

No. of damaged bars	$T_{\text{pulsation}}$	n	slip
	%	rpm	%
0	2,0	1400	6,7
1	2,2	1395	7,0
3	6,8	1380	8,0
3 + 1	6,9	1370	8,7
5	10,8	1358	9,5
5 + 3	17,6	1350	10,0
7	12,5	1340	10,7
7 + 5	34,4	1320	12,0

The obtained investigation results show clearly that rotor cage fault has significant influence on the motor torque pulsation and slip. Motor torque pulsation and slip are proportional to the number of the damaged rotor bars.

4. CONCLUSIONS

Little induction motor rotor cage fault does not influence on the running motor noticeably but the fault can be extended due to additional thermal and mechanical stresses caused by the higher motor temperature rise and non-uniform temperature distribution in the rotor. Extended induction motor rotor cage fault has significant influence on the motor temperature rise, torque pulsation and slip what is strongly harmful for the running motor and can cause the motor fault preventing it from further running.

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