Controversial Aspects of Stray Loss in Cage-Induction Motors

By M. Z. Mohammed*, Ph.D. & Prof. O.I. Butler+, D. Sc.

1. Introduction:

Stray losses in cage induction motor have been the subject of many papers in the recent years, yet there is no universally accepted definition. An old definition for stray losses stated that they are the additional losses which occur in induction motor and which are not included in the normal design calculations (1).

Such a definition is too vague, since it fails to give any reason for their existance, their nature or their components. It is as well inaccurate because of its dependance on a specific design method; i.e., different designers get different estimations for stray losses. Stray losses have been defined also as those losses occurring in rotating electric machines in addition to the normal copper, iron and friction losses (2). Such definitions which are not clear at all result in a confusion whether to consider a specific type of loss as a stray loss or not.

Load losses were defined as the difference between the total power losses of the machine on load and the losses determined by the loss segregation method, the latter contains friction and windage losses, stator core and copper losses and rotor copper loss (3).

* Dr. Mohammed is the Head of the Dept. of Electrical Engineering, University of Mosul, Mosul - Iraq.

+ Prof. Butler is with Dept. of Electronics & Electrical Engineering University of Sheffield, Sheffield - England.

Hence any no load stray loss is not included in this definition. For this reason stray losses were divided into stray no-load losses and stray load losses.

Few definitions were standarised for the stray load loss which is the major part of stray loss. Some of these are:

(I) B.S. 205-1943 defines them as the additional losses where-ever occurring, caused by the load current due to change in flux distribution and to eddy currents (4).

(2) VDE 0530 defines them as those losses which are neither no load losses (iron and friction losses) nor Joulean dissipation losses in the winding corresponding to the d.c. resistance or transitional at the slip ring (5).

(3) According to the American Standard Test Code they were defined as that portion of the total losses in a machine not accounted for by the sum of friction and windage, Stator I^2R loss, rotor I^2R and no-load core loss.

2. Classification of Stray losses

There has been more than one way of classification for the components of stray losses according to their origin, frequency or the place where they occur.

Stray losses may be classified as those due to theoretical imperfections and those due to industrial imperfections (7). The inaccurate calculation of the iron loss & addy currents in stator conductor are examples for the first, and the interbar losses in the rotor are examples for the latter.

It is possible to divide losses as well into those due to the fundamental frequency and those due to its harmonics . Both these components may be considered as stray losses or otherwise according to the British Standard because the definition does not make it clear enough. However Weppler(5) made it very clear that the fundamental frequency losses due to imperfect bar to coreplate insulation are not stray losses.

Stray losses when classified according to the places where they occur are divided into surface losses, tooth pulsation losses, I^2R losses due to tooth pulsation airgap harmonic flux and stator harmonic, and the slot and overhang eddy current losses.

3. Interbar losses

These are only part of the stray losses in cage induction motors, however, the contraversy lies in this field. The origin of the interbar losses and the place where they occur are very clear. Hence the losses due to imperfect bar to coreplate insulation may be classified according to these due to the fundanental waveform and those due its harmonics. Each of these waveforms will produce losses in the bar, interbar, and endring resistances. At least one of the above mentioned losses is not stray ; i.e. the bar losses due to the fundanental waveform. But the problem is that the losses in the bar in the case of imperfectly-insulated rotor bars will be more than those in the cage of perfectly-insulated rotor bars. Hence the question which ought to be answered is whether this increase in the fundamental losses above the case of perfectly-insulated rotor bars is to be considered as stray or not?

4. <u>Discussion</u>

In trying to answer the above question in the light of the definitions of section (I), it is clear that they are considered by the VDE[5] definition as normal losses and not stray, since they occur in the bars although they are due to imperfect bar to coreplate insulation.

Some authors emphasized the classification of such losses as being pure losses. American test code[6] stands, as well, in this side since these losses are I^2R losses in the rotor.

The british standard[4] can be as well understood to aid the second classification, although it does not show that very clearly.

When studying the harmonics losses, at least one definition tends to consider the losses in the interbar path only as stray; i.e., it considers the harmonic bar losses as normal losses (5) .

Before trying to solve this contraversy a clear definition is to be put forward first, and then the losses are to be tested accordingly. Two definitions are propòsed here for stray losses :-

1. The reduction at any speed of the output power below that corresponding to operation with perfectly-insulated rotor losses and a fundamental-flux waveform only in the airgap; i.e., with no harmonic flux waveform in the airgap nor transverse currents in the rotor.
2. The diffenence between (I) The input power calculated on the basis of the equivalent circuit corresponding to only the fundamental-flux

component in the airgap with a perfectly insulated cage and (ii) the test value of input power loss less the friction and windage losses".

From the above definitions, the following components are considered as stray losses:

(i) All harmonics losses in the bar, interbar and endring resistances, even if they produce positive torques.

(ii) Fundamental waveform losses in the interbar resistance.

(iii) Exess of fundauental bar plus endring losses in the case of imperfectly insulated rotor bars above those in the case of perfectly- insulated rotor bars.

5. Conclusions

A clear distinction between the components of losses due to the bar to coreplates imperfect insulation is made. All harmonics losses are considered as stray losses. Fundamental waveform in the interbar path and the exess over the case of perfect insulation in the bar and endrings are considered as stray losses as well.

6. Aknowldgement

The authors are grateful to the facillities offered at both department of electrical engineering at University of Mosul, Mosul-Iraq and the department of electronics and electrical engineering, University of Sheffield, Sheffield-England.

7. Refernces

1. Bird, B,. M. "Measurement of stray load losses," A Ph. D. thesis, University of Bristol, 1963.

2. Barton, T. H. and Ahmad, V. "The measurement and Prediction of in-duction motor stray loss at large slip." A. I. E. E. Trans. Jan 1957 PP. 299 - 304.

3. Christofides, N. "Origins of load losses in induction motors with cast aluminium rotors". Proc. I. E. E. 122 No. 12, Dec. 1965, PP. 2317 - 2332.

4. British Standard Institution",."Methods of declaring efficiency of electrical machines". B. S. 269, 1927,. Incorporating amendment March 1957.

5. Weppler, R. "Stray losses and torque curves of three -phase asynchronous motors with squirrel - cage rotors". VDE Fachler 1966, 24 , PP 209 - 216 (in German).

6. A. I. E. E. Committee "Stray load lose measurement in induction machines". I.E.E.E. Transaction April 1954,PP. 67-71.

7. Change, S.S.L. " Physical Concepts of stray load loss in induction Machines". A. I. E. E. Trans. Feb. 1954, PP. 10 - 12.