Study on Iron Loss in Permanent Magnet Synchronous Motors

Akihiko Takahashi and others

1. Introduction

Permanent magnet type synchronous motors (abbreviated as PM motor hereafter) are widely used mainly as small capacity servo motors. However, flux-weakening control becomes necessary, which reduces the field magnetic flux as the rotating speed increases because the terminal voltage tends to increase due to the counter-electromotive force caused by the field magnetic flux. In the PM motor, in which the field magnetic flux is produced by a permanent magnet, the increase of terminal voltage caused by the counter-electromotive force can be suppressed by utilizing the demagnetization function of the d-axis armature reaction which acts in the direction of the direct axis of the permanent magnet, even though the field magnetic flux cannot be directly weakened. PM motors can thus have a wide range of variable speed operation.

PM motors can be made to operate very efficiently by using current control taking the motor loss into consideration. In this control, numeric modeling of the iron loss is important. Control parameters involving the iron loss are also considered.

Thus, the effects of motor iron loss must be carefully controlled in order to make the motor driving system efficient and to improve the control capability. The iron loss must therefore be quantified when flux-weakening control is performed during high-speed operation

In this paper, we investigate the iron loss using only the permanent magnet field and the iron loss when the d-axis armature current flows, in order to determine the motor loss quantitatively at flux-weakening control in the high-speed operating range. Firstly, we show the general expression of armature iron loss, then show how the air-gap flux and armature reaction flux are treated for flux-weakening control. We also separately investigated the iron loss using only a permanent magnet field, and the loss at flux-weakening control.