Abstract

In this speech, optimal design of high speed large power permanent magnet synchronous motors (PMSM) will be presented, taking a 350kW and 13.5krpm non-salient PMSM as an example. Firstly, it is critical to determine a proper level of PM-excited flux linkage in the armature windings, so that for a given high speed motor the supply voltage can be fully utilized, the motor armature current can be minimized, and the power factor can be enhanced. Of course all of these are associated with proper control strategies, whilst the motor must have sufficient potential capability to cooperate with the control strategies. In other words, the motor itself and the control method should be systematically designed. Specific considerations on electromagnetic design will be presented. For example, PM rotor structure need be designed to provide sufficient strength against centrifugal force and meanwhile to generate the required level of PM flux, whilst stator winding structure should be designed with appropriate inductance, since high operation frequency could cause high armature impedance. Clearly, high armature impedance may deteriorate the motor power factor, but may also enhance the field modulation capability by armature currents, hence, compromise is essential. On the other hand, during electromagnetic design some special losses such as extra winding ohmic loss and rotor eddy current loss due to high speed operation should be particularly suppressed, as these losses may cause high temperature rise and may even damage the motor. Rotor stress due to high speed operation need be considered critically. Examples of reducing local over-stress in the rotor will be given, whilst such techniques often harm the motor electromagnetic performance. Therefore, compromise is required again. Also, design of rotor dynamics is important, in that rotor resonance must be avoided. Basically it is preferable to make a short rotor with a thick shaft to increase the critical resonant frequency. But this will usually enlarge the rotor diameter and consequently increase the rotor stress. On the other hand, high speed machines enjoy the merit of high power density, but also suffer from the problem of high loss density. Hence, thermal design is particularly required. Winding impregnation or encapsulation can be employed, whilst liquid cooling or forced air cooling can be rather effective, hence, single- or even double-phase fluid dynamics computation is required, coupling with thermal analysis. Furthermore, some measures to enhance the fluid dynamics such as introducing extra air channels in the stator core will affect the motor electromagnetic performance. Clearly, various physical fields are deeply coupled in the high speed large power motors, thus, compromises must be made. Multi-physics analysis and design are not only essential, but also usually need be iterated, so as to achieve an overall satisfactory performance.