Researches on the Behavior of Vibration and Noise of an IPM Motor on HEV

Zeng Jinling
Lu Bingwu, Huo Fuxiang, Sun Xiaoji

Abstract :
Hybrid electric vehicles are becoming more popular, but the higher efficiency and miniaturization requires of the IPM motor result in vibration and noise, which make electric motor as the major vibration and noise source of the hybrid electric vehicle. It is well known that the source of these problems will be difficult to be pinpointed when the motor is mounted in vehicle. Meanwhile, a significant amount of time and money may be cost in manufacturing process of these faulty motors. So, how to quickly identify and reduce the vibration and noise of electric motor has become a necessity. In this paper, a numerical analysis method will be provided to expeditiously predict and understand the behavior of vibration and noise of an IPM motor in the stage of product design.

Keywords hybrid electric vehicle, IPM motor, NVH, numerical analysis method

Researches on the Behavior of Vibration and Noise of an IPM Motor on HEV

Zeng Jinling, Piao Yinzi, Lu Bingwu, Huo Fuxiang

State Key Laboratory of Comprehensive Technology on Automobile Vibration and Noise & Safety Control

中国第一汽车集团公司技术中心
CHINA FAW GROUP CORPORATION R&D CENTER

中国第一汽车集团公司技术中心
CHINA FAW GROUP CORPORATION R&D CENTER

Abstract: Hybrid electric vehicles are becoming more popular, but the higher efficiency and miniaturization requires of the IPM motor result in vibration and noise, which make electric motor as the major vibration and noise source of the hybrid electric vehicle. It is well known that the source of these problems will be difficult to be pinpointed when the motor is mounted in vehicle. Meanwhile, a significant amount of time and money may be cost in manufacturing process of these faulty motors. So, how to quickly identify and reduce the vibration and noise of electric motor has become a necessity. In this paper, a numerical analysis method will be provided to expeditiously predict and understand the behavior of vibration and noise of an IPM motor in the stage of product design.

中国第一汽车集团公司技术中心
CHINA FAW GROUP CORPORATION R&D CENTER

Why chose JMAG in FAW ?

➢ Friendly graphical interface

Firstly, learning and application of JAMG are so easy. For a beginner, it may take him only two days to master Designer. Take me for example, in fact I was a structural analysis engineer two years ago. At the beginning of last year, I started making motor finite element analysis. **JMAG** was the first software used to simulate motor, later I tried other software, such as **ANSOFT** and **MAGNEFORCE**, but I found it was difficult to learn them. Furthermore, My colleagues who had used **ANSOFT** for three years in colleges also can't expertly use it to solve practical engineering problems. So that let me the layman to analyze motor by using **JMAG.**

Secondly, JMAG has some friendly interfaces with other FEA software, such as **ABAQUS, VIRTUAL_LAB** and **SIMULINK**. As is known to us, **ABAQUS** is a mainstream structural analysis software, especially in the automobile industry. **VIRTUAL_LAB** is a preferred software to solve the vibration and noise problem. **SIMULINK** is a popular control software. **JMAG** can make some coupling analyses become so simple. This presentation is based on coupling JMAG with VIRTUAL_LAB.

➢ Rich material data base

JMAG has more than 700 materials in the database. It may be almost worthless for some people, but it is very precious for other people who researched in motor area at the start and haven't any accumulation. If these people want to master performances of a motor by using FEM , they need cost a lot of time and money to obtain material parameters. However, they can quickly gain the simulation results based on the material database of JMAG.

➢ Attentive customer service

I believe that you also share this point. I am a beginner and have some problems about software application and professional knowledge, but technical supports of JSOL always respond my questions in short time . I take this opportunity to express my thanks to Mr. Hiroyuki Sano and Miss Yao.

3

中国第一汽车集团公司技术中心
CHINA FAW GROUP CORPORATION R&D CENTER

Cases using JMAG in FAW

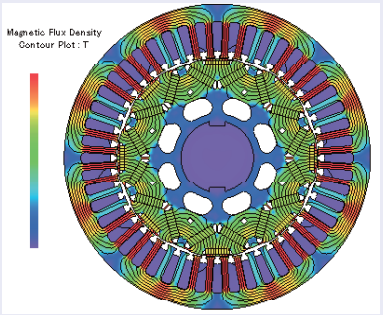


Fig1. magnetic flux density contour plot and flux lines

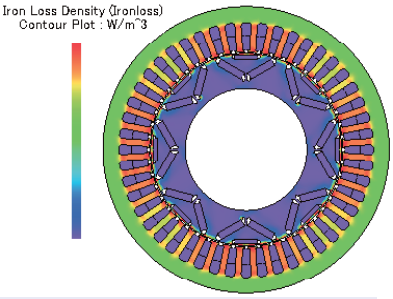
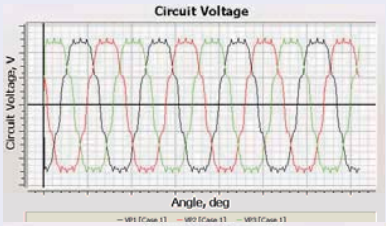


Fig2. iron loss density contour plot



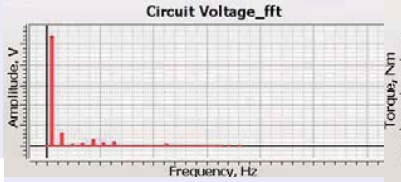


Fig3. EMF curve and FFT of EMF curve

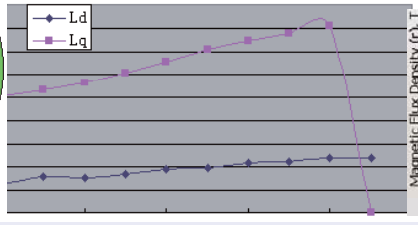


Fig4. inductance curve

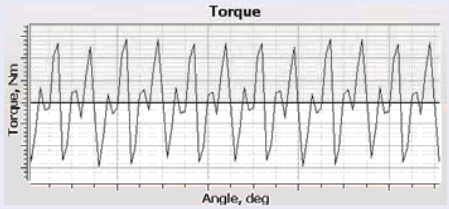


Fig5. cogging torque curve

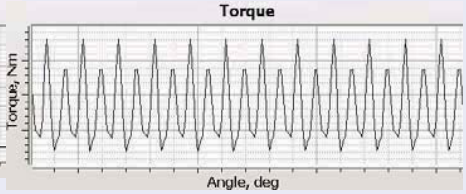


Fig6. electromagnetic torque curve

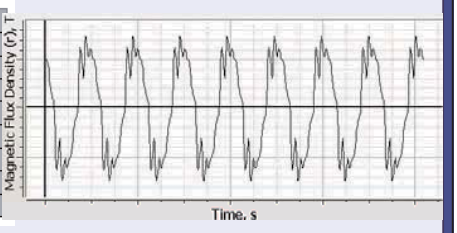


Fig7. magnetic flux density curve of gap

4

中国第一汽车集团公司技术中心
CHINA FAW GROUP CORPORATION R&D CENTER

Cases using JMAG in FAW

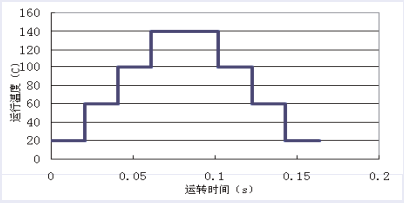


Fig8. Diagram of IPM operating temperature curve

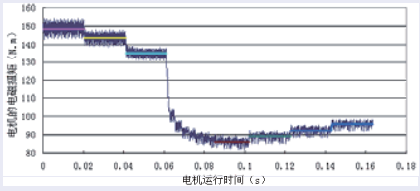


Fig9. Torque curve of IPM at operating different temperature

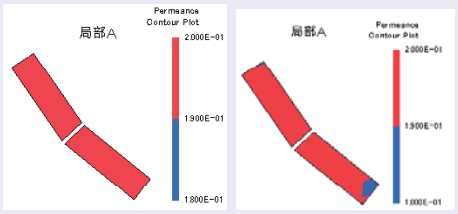


Fig11. Permeance contour plot of magnet operating at 20 ℃

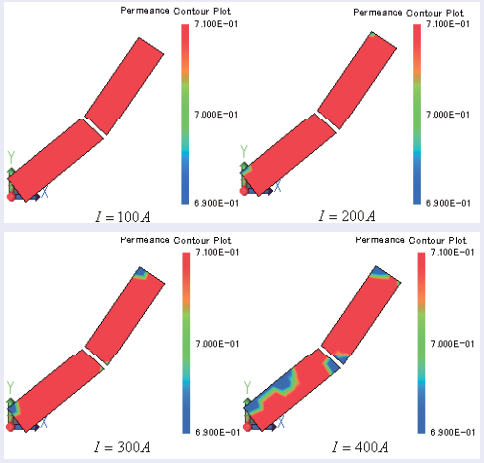


Fig12. Permeance contour plot of magnet operating at different currents

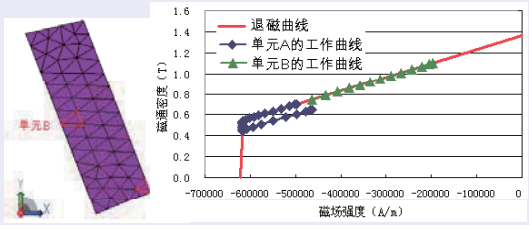


Fig 13. operating curves of different points on a magnet

中国第一汽车集团公司技术中心
CHINA FAW GROUP CORPORATION R&D CENTER

Cases using JMAG in FAW

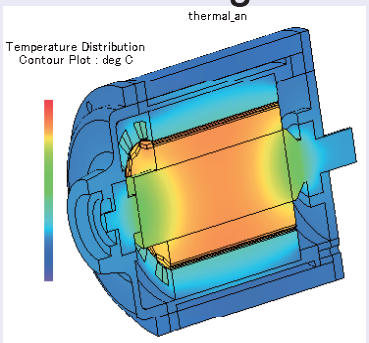


Fig14 . Temperature distribution contour plot of a IPM

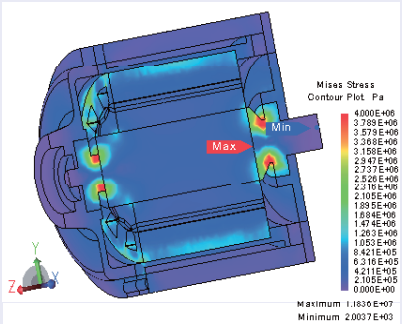


Fig15 . Von-mises stress contour plot of a IPM

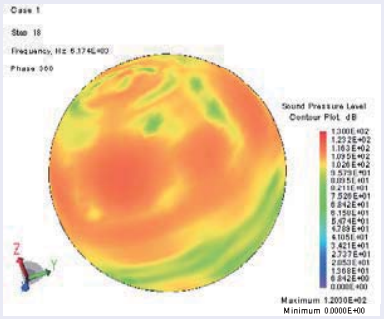


Fig16 . Sound pressure level contour plot of a IPM

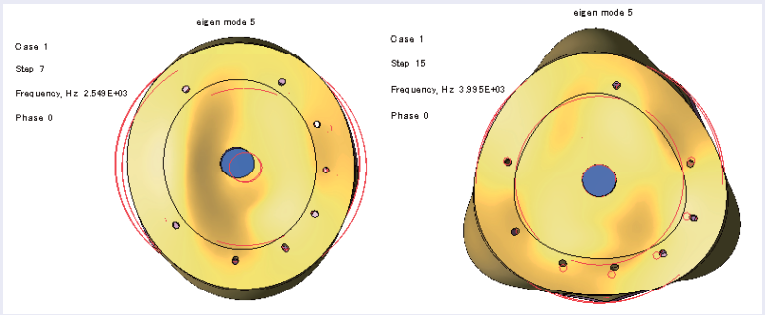


Fig17 . Eigen mode of a IPM

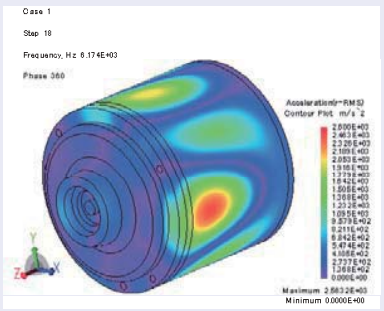


Fig18 . Vibration acceleration contour plot of a IPM

6

中国第一汽车集团公司技术中心
CHINA FAW GROUP CORPORATION R&D CENTER

Cases using JMAG in FAW

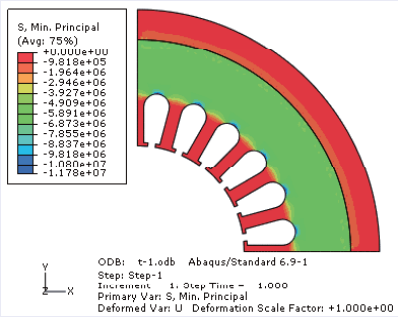


Fig19. Minimum principal stress contour plot of stator core in ABAQUS

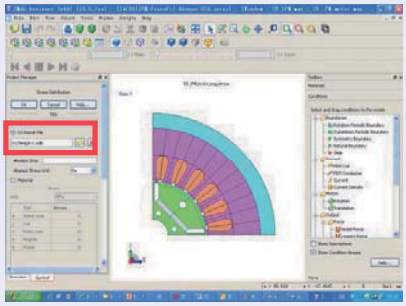
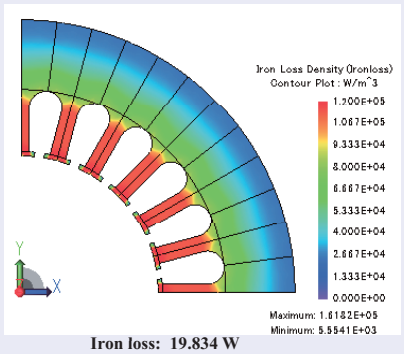
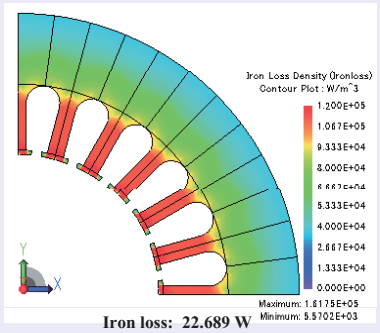


Fig20. Minimum principal stress contour plot of stator core in ABAQUS



Iron loss: 19.834 W

Fig21. Iron loss density without stress contour plot of stator core



Iron loss: 22.689 W

Fig22. Iron loss density with stress contour plot of stator core

7

中国第一汽车集团公司技术中心
CHINA FAW GROUP CORPORATION R&D CENTER

NVH simulation coupling JMAG with Virtual_lab

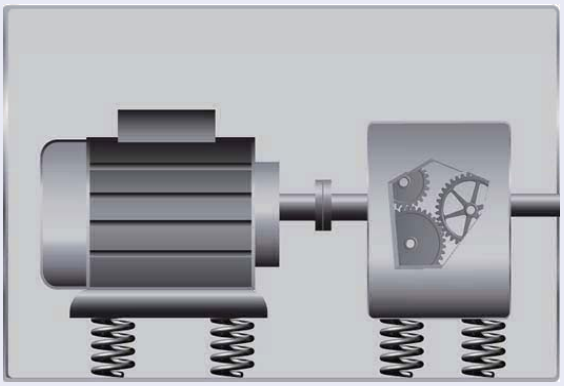
Electrical Motor Vibration and Noise

➢ What are exciting forces which cause the electric motor vibration and noise.

- **electromagnetic force**
- **centrifugal force**
- **unbalanced force**
- **other forces**

➢ How to transfer the electric motor vibration and noise.

- **transmission path**
- **mechanical assembly model**
- **structural response**



8

中国第一汽车集团公司技术中心
CHINA FAW GROUP CORPORATION R&D CENTER

NVH simulation coupling JMAG with Virtual_lab

Integrated Simulation Environment

CAD Geometry → Exciting Force → Mode → Vibration → Noise

Catia or Pro/E

JMAG or Ansoft

Abaqus or Nastran

Virtual_Lab

Virtual_Lab

- Quickly predict the vibration and noise
- Fast optimize the structure

9

中国第一汽车集团公司技术中心
CHINA FAW GROUP CORPORATION R&D CENTER

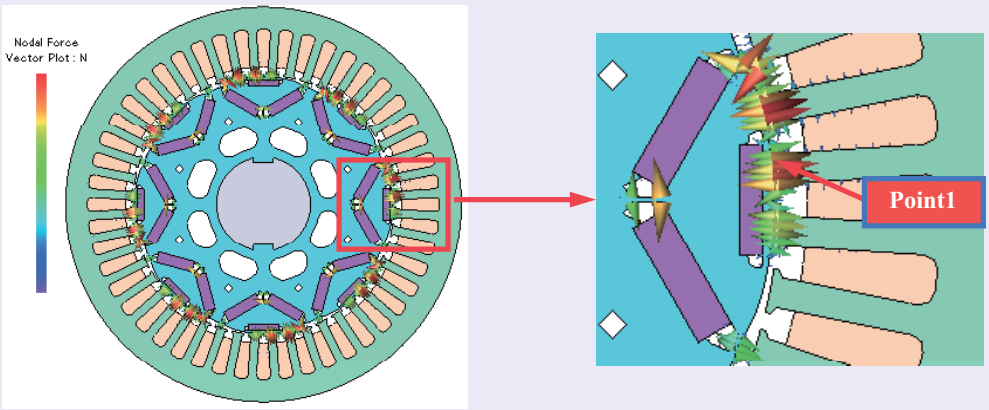


Fig23 . Electromagnetic force distribution

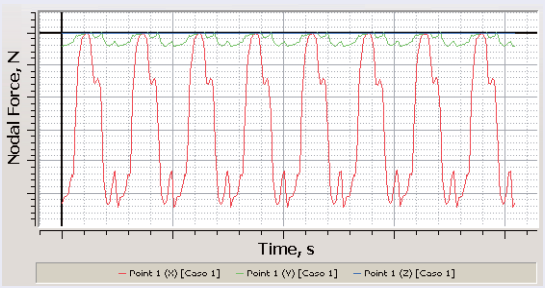


Fig24 . Electromagnetic force components of a measuring point in X,Y and Z axial direction

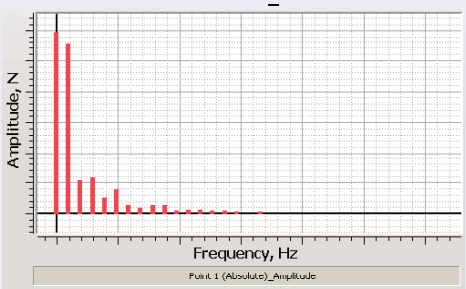
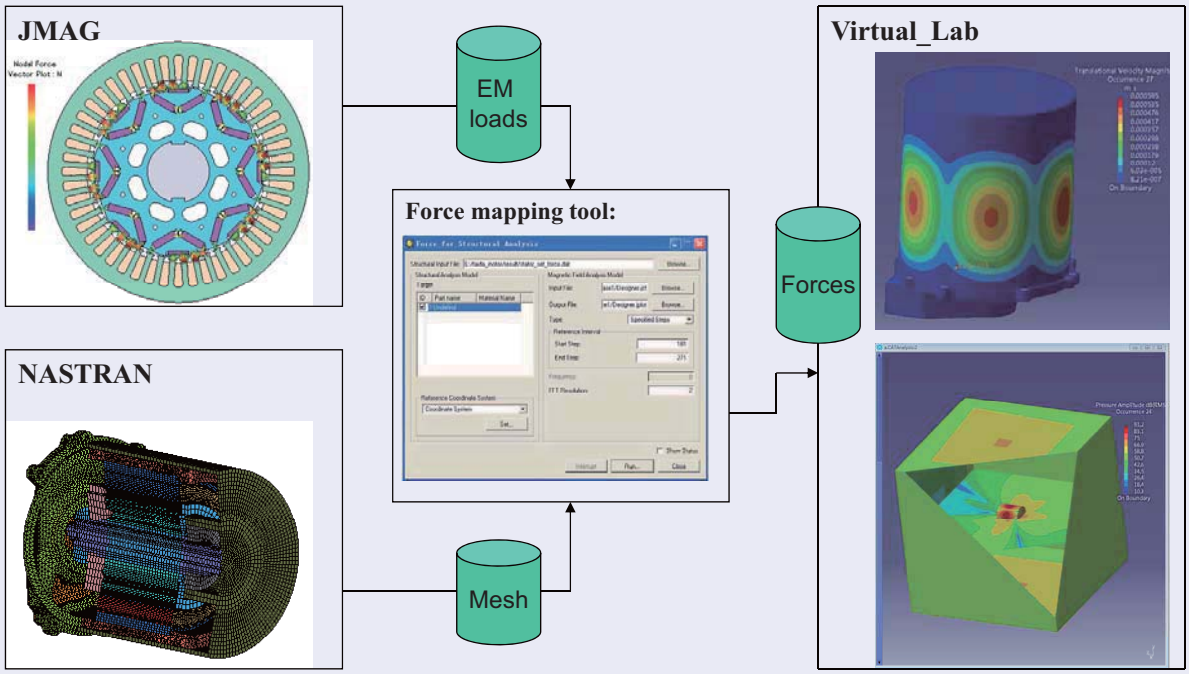


Fig25 . Frequency components diagram of the electromagnetic force at a measuring point

10

中国第一汽车集团公司技术中心
CHINA FAW GROUP CORPORATION R&D CENTER

NVH simulation coupling JMAG with Virtual_lab



11

中国第一汽车集团公司技术中心
CHINA FAW GROUP CORPORATION R&D CENTER

NVH simulation coupling JMAG with Virtual_lab

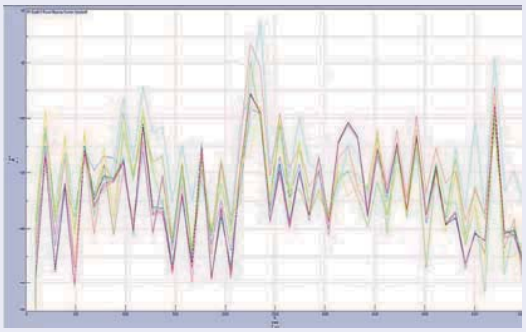


Fig26 . Vibration velocity level curve of a IPM

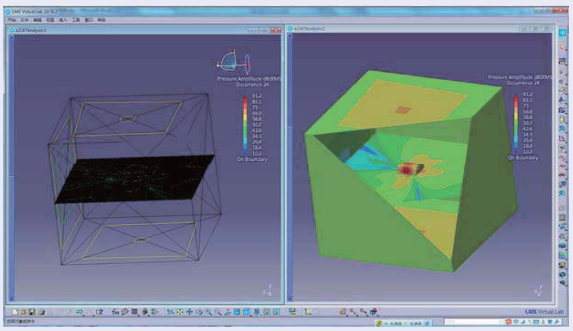


Fig27 . Sound pressure distribution contour plot of a IPM

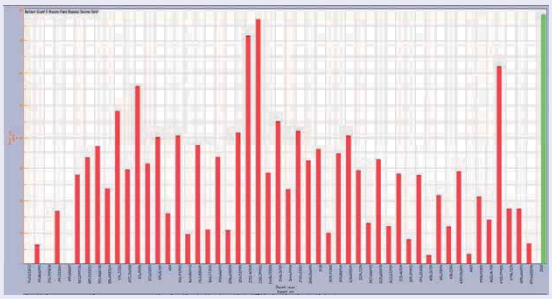


Fig28 . Acoustic power spectrum diagram of a IPM

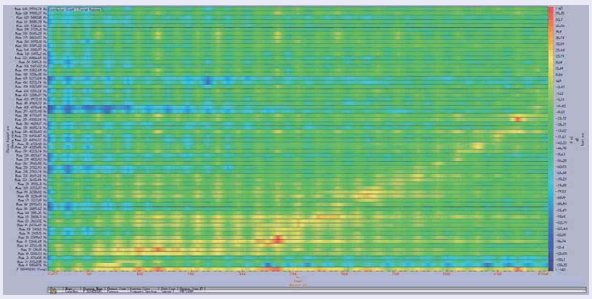


Fig29 . Modal acoustic contribution spectrum contour plot

12

中国一汽

关爱自然 服务社会

CARE THE NATURE AND SERVE THE SOCIETY

——让汽车更清洁 更节能 更安全

Contribute cleaner, safer and more energy saving vehicles

Thank you for your attention!