Simulation Technology for Electromechanical Design

JMAG®

JMAG Newsletter

March, 2013

Simulation Technology for Electromechanical Design
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JM AG

Contents

JMAG Newsletter: Highlights of the March Issue

This is the final issue of the JMAG Newsletter for this fiscal year.

For this month's Implementing JMAG, we interviewed Mr. Charles R. Frontczak from Tempel Steel, the world's leading manufacturer in the field of magnetic steel sheet. He spoke openly on how JMAG can be used to select magnetic steel sheet while striving for cost performance, and what functions are useful for dealing with extensive design proposal trials at the initial design stage. We are happy to present these to you along with content from his presentation at the JMAG Users Conference 2012.

The Technical FAQ focuses on the many questions we receive. At the moment, we are requesting that JMAG-Studio users move over to JMAG-Designer. We reply to some of their concerns, such as whether the files they have been using until now can be used in JMAG-Designer.

Also, we have redesigned our Technical FAQ webpage as of March. It is now possible to search by function or by motor, transformer, or other application, so searching has become even easier. Please feel free to use this along with JMAG technical support.

There are an almost infinite number of technical documents and papers in the world. In our Paper Introduction, we are pleased to present papers that engineers at our company have found useful. This month, we introduce materials necessary for analysis, focusing on people who are planning to begin using analysis for large transformers. It can be very difficult to take on a whole new field. This issue introduces materials that have been useful for our engineers in solving problems and gaining basic knowledge.

Finally, we would like to inform you that JMAG-Designer Ver.12.1 is planned for release in May, 2013. Ver.12.1 will include general-purpose interface mapping functions, which will greatly improve its ability to link with other software. Constraint functions will also be improved. In addition to these, it will be faster and easier to use, thanks to functions for easy creation of 3D models, functions to improve reusability of CAD models, mesh robustness functions, functions for considering distortion due to processing, and others. Further details will be provided in the next issue, so please look forward to that.

The JMAG Newsletter is intended for everybody, from those who are currently using the product, to those who have not started yet, to those who have just started using it.

By all means, take this chance to introduce it to someone nearby.

This edition of the JMAG Newsletter is packed with more content than ever. We hope you enjoy it.

JSOL Corporation

Electromagnetic Engineering Department, Engineering Technology Division

Implementing JMAG

Tempel Steel, Evaluation and Selection of Electrical Steels using Simulation

The world's leading manufacturer in the field of electrical steels, Tempel Steel. Tempel Steel has continued to provide electrical steels used in a variety of electrical devices such as motors for all applications including vehicles, generators, and transformers. JSOL's electromagnetic field analysis software "JMAG" is used in their development.

We interviewed Mr. Charles R. Frontczak and heard how JMAG is used to select appropriate electrical steels on a cost-benefit basis. This report also includes content from the presentation he gave at the JMAG Users Conference 2012.

— Can you give us some details about Tempel Steel and its business activity?

C.R.Frontczak:　Tempel steel is a 65 year old company and is still privately held. It deals primarily with precision electrical steel stamping for motor/generator and transformer industry. We also perform laser-cutting, deburring, recoating as well as die-casting and welding operations. We utilize the engineering know how experience along with precision tooling and presses that range from 10 to 550 Tons. Progressive as well as blank-and-notch dies are designed, built and maintained by Tempel Steel. We are also a trusted name when it comes to electrical steel performance data. Headquartered in Chicago, Illinois we have a global footprint with operations in Canada, Mexico, China and India.
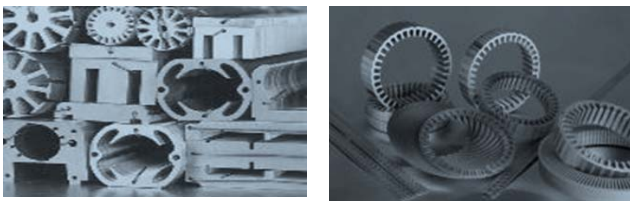
— What kind of work are you doing?

C.R.Frontczak:　I work within the Marketing Technical Services (MTS) group as the electro-magnetic (EM) design engineer for electro-magnetic devices (i.e. motors, generators,

Tempel Steel
Sr.Electric Motor Design Engineer,
Charles R. Frontczak
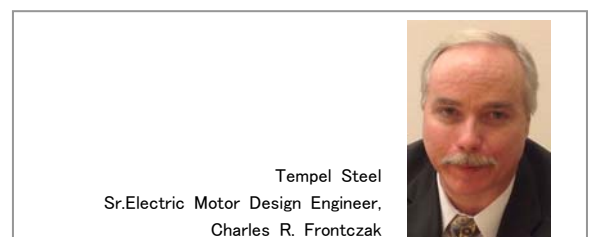
transformers, ignition coils, etc.). More specifically, I show our customers how their designs perform through simulation with different types of electrical steel grades using the JMAG software. Cost reductions and improved efficiencies usually drive our customer's requests.

— What initially triggered you to use JMAG?

C.R.Frontczak:　The initial trigger was to fill a need that was recognized by Tempel Steel, which was to have an EM engineer helping their customers make an economical decision in choosing their designs and materials. We needed an FEA tool to accurately capture the losses and predict the performance quickly and efficiently. JMAG fits our need with being flexible and accurate with a quick turn-around time.

— How is it useful for your business and study?

C.R.Frontczak:　I value JMAG from its easy interface, to the parametric case studies that I

create in solving customer scenarios. For example, I set-up different lamination stack lengths and adjust the other parameters such as steel materials, copper and or aluminum turns and resistance to determine flux densities and iron losses. This enables me to improve efficiencies and reduce materials to cut costs.
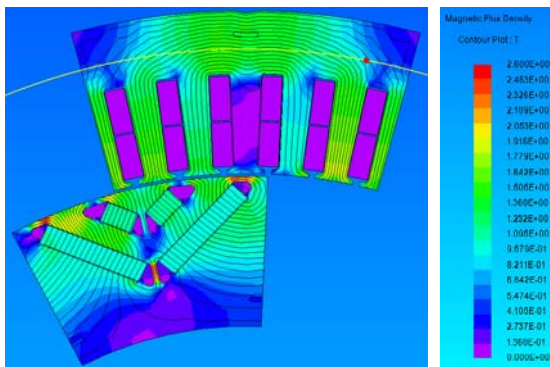
Flux Density of IPM motor

— What would you estimate as the time difference between setting up and getting results in JMAG compared to other tools or non FEA tools?

C.R.Frontczak: I can setup a JMAG model within 3-4 hours and usually have a rough answer that same day. Then by tweaking the mesh tighter and setting-up the parametric case studies… I can send the model to a batch queue, let it run over night and have my answers the next morning. Without JMAG, I would be required to set-up the magnetic circuit on paper or use a homemade spreadsheet program to calculate the flux densities. Then I would calculate the performance characteristics based on the flux values and determine the power loss and thereby efficiency. However, JMAG provides a wealth of data that I can dig into to analyze the model. Additionally, Tempel Steel has the ability to fully test all electrical steel properties with a wide range of inductions and frequencies. This data allows me to input accurate steel curves which enables the FEA analysis to become more powerful.

— Anything you would like JMAG to improve?

C.R.Frontczak: Yes. I still do some things as "Old School". Example is when I assign FEM coils in my model; I link one coil group at a time to my circuit of individual FEM coils. This way the coils are not bunched together, and I can change their values during multiple studies. In doing this however, I would like a numbering and color coding sequence to take place as to avoid assigning FEM coils to duplicate geometry. I indicated this idea to the people at JMAG and they were very interested in making this change. In fact, my experience has been that they are very willing to adapt their software to customer input.

— What is your outlook for the future regarding electrical steel and its market?

C.R.Frontczak: Our customers are always looking to improve efficiency and reduce costs. Therefore, they look to us to help them in their efforts. Electrical steel pricing will remain volatile, so it's imperative to have an FEA tool such as JMAG to look at performance behaviors as steel materials may change due to pricing pressures.

— Finally, do you have any opinions/comments you would like to share with JMAG/JSOL?

C.R.Frontczak: Well, I do appreciate the on-going technical support, and the organization is always interested in improving their software. In fact, since I purchased JMAG 2 years ago I've seen updates every 6 months. I'm glad I did my initial research on Finite Element software and chose JMAG. It has made my job easier and fun to be able to work on so many different designs and to have detailed results and images to share with our customers.

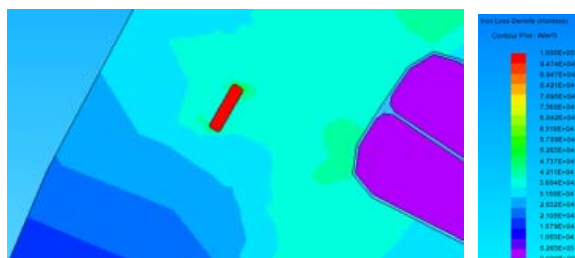Thank you very much, Mr. Charles R. Frontczak

Interviewer: Dheeraj Bobba, Powersys Solutions

Presentations of JMAG Users Conference 2012

Evaluation of Different Electrical Steels and Iron Loss evaluation of inter-locks vs welds vs bonded lamination cores in IPM Hybrid Motor using JMAG

This presentation focuses on electrical steel grade selection for Hybrid I.P.M. Electric Motors. Choosing the proper steel is the foundation of any good electro-magnetic machine. In most cases, there is insufficient data available for accurate properties of steel characteristics, especially high frequencies. Tempel Steel has developed methods, including Epstein and ring tests that generate a comprehensive range of core loss, permeability and magnetizing force data as functions of both frequency and induction. The use of this data input in JMAG allows the user to make educated decisions and places numerical values for each case study.

Additionally, it has added the iron loss differences between three methods of securing lamination stacks. These three methods are inter-locking, welding, and bonding. This analysis was accomplished with the JMAG 2D software, future effort will incorporate JMAG 3D simulation analysis, and lab test results.

Iron loss density of the interlocked model

Cited verse JMAG Users Conference 2012

Presentations, Tempel Steel Company Mr. Charles R. Frontczak, "Evaluation of Different Electrical Steels and Iron Loss evaluation of inter-locks vs welds vs bonded lamination cores in IPM Hybrid Motor using JMAG"
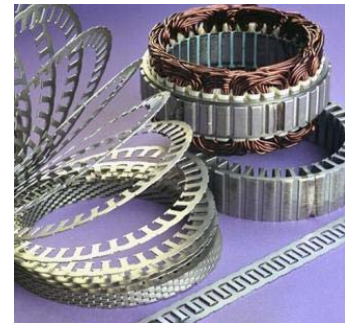
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Is FEA Effective in Motor Design?
Issue 2 Making Use of FEA in Detailed Design

This issue is aimed at those designing or using motors, to let you know the effectiveness of utilizing simulation. We hope you will find this useful as a reference for designing better motors.

Overview

As computer hardware and software becomes more advanced, finite element method electromagnetic field analysis (hereafter FEA) is being used more, and its real effectiveness in development facilities is growing.

However, if you talk to people who are not using FEA now, there are many who say things like "I've heard that FEA is good, but we can accomplish the same things with our current development process, so we don't need it," or "It seems like it would take a lot of time and effort to adopt it."

This series attempts to respond to the concern of "why is FEA effective in motor design?" We hope this helps you to understand the benefits of using FEA for better motor design.

In Issue 1, I discussed the use of FEA at the concept design and initial design stages in motor design. Here in Issue 2, I will present uses for FEA at the detailed design stage. The goal at this stage is to optimize design variables based on rough proposals determined at the concept and initial design stages, and then to settle on design parameters such as measurements, conditions, and material properties for the various parts. We will discuss effective use of FEM in design optimization at the detailed design stage, and how to analyze FEA results and apply them to designs.

Improved Performance and Development Issues in PM Motors

The following is an outline of the difficulties in improving performance in detailed design, not limited to motors.

1: Balancing trade-offs to find optimal values

There is a wide range of issues to solve in order to improve motor performance. Many of these have trade-off relationships with others, such as reducing iron loss to improve efficiency and reducing torque variation so it will not cause vibration, so when one is prioritized, others are hindered, and finding the proper balance is never easy (Fig. 1). For example, magnet volume can be increased to improve output density, but this makes cost reduction more difficult. In order to choose the best values among these complicated trade-off relationships, designers must have quantitative knowledge of the relationships between solutions to the various problems, and FEA that encompasses the physical phenomena is vital for this.
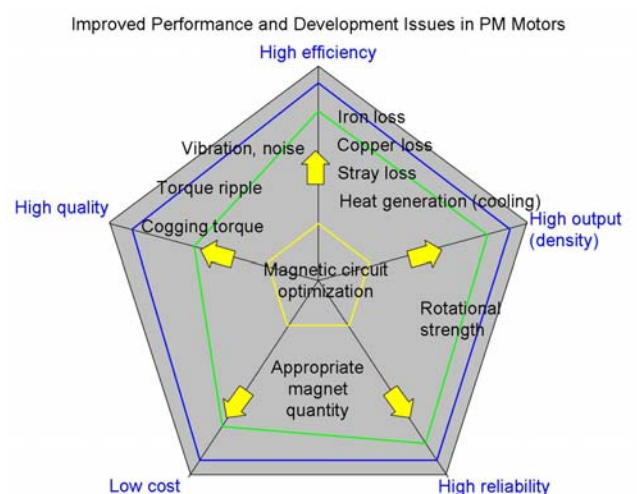

Fig. 1 Improved performance and development issues in motors

2: Pushing it to the limit

Motors are already quite efficient compared to other energy-conversion devices. Improving this efficiency even further is the goal, so efforts must be made to poke into every little corner in order to reduce loss. FEA is unrivalled for the sort of minute test studies needed for this purpose.

3: The need to draw out new abilities

If all issues could be solved by extension of the design techniques used in the past, then veteran designers would be able to produce design proposals using magnetic circuit methods, etc., based on their experience without using FEA. However, it becomes necessary to jump up to a new level over past experience in order to push optimization of trade-offs all the way to the limit. In cases like these, it is extremely hard to accomplish only by extrapolating past experience, but with FEA, even unconventional ideas that would give pause for prototyping can be tried out.

Creating Performance in Detailed Design

Models can be made precisely and even nonlinear magnetization properties for materials can be accurately modeled in FEA, so the complex electromagnetic phenomena occurring inside a motor can be reproduced. Designers' ideas can be brought to life and evaluated right on the desktop, allowing better design proposals to be advanced. Below is an explanation of the benefits of FEA, including concrete examples.

Reduction of Cogging Torque

For example, there are times when you may want to reduce cogging torque in a high-end motor. Cogging torque is highly sensitive to details of a motor's geometry and is also affected by material properties, so it poses a difficult design theme.

It is well-known that one solution to reduce cogging torque is to add skew to the rotor or stator, but because this has demerits such as a fall in productivity, reduction

in torque coefficient, forces generated in the slant direction, etc., designers are instead expected to reduce cogging torque by optimizing magnetic circuit geometry rather than adding skew. Although it is easy to talk about optimizing magnetic circuits, the parameters are in fact quite complex. A main cause of cogging torque is intermittent changes in magnetic resistance in the stator due to the coil slots, so it can be reduced by appropriately designing the pole arc angle of the magnets and the slot pitch. Figures 2 and 3 show a study of variations in pole arc angle with the design parameter of magnet width in an SPM motor. In this study, with magnet width varied from 14 mm to 11 mm, minimization occurs at 12.5 mm, being about half compared to the initial value of 14 mm. However, if magnet width is made any thinner than this, cogging torque starts to increase, and is much higher at 11 mm even than at the initial value.
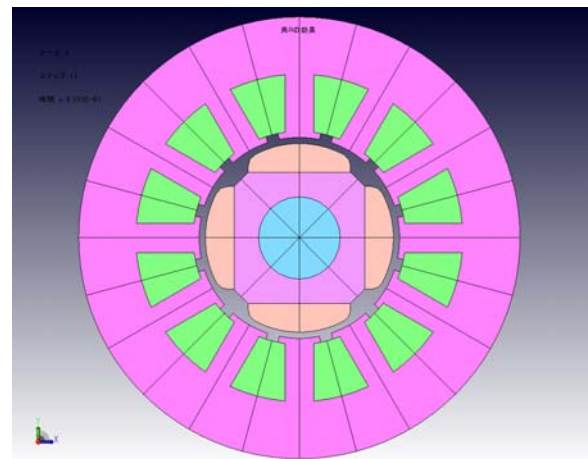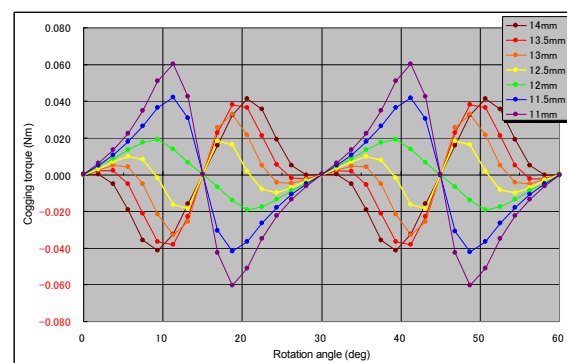
Fig. 2 SPM motor geometry

Fig. 3 Differences in cogging torque due to magnet width

In an actual motor, the magnets' corners are given an angle R in order to prevent magnet breakdown and peeling of the magnets' surface treatment. For the magnetic circuit, this makes switching at the boundary more lenient, so it can be expected to have an effect on cogging torque reduction as well. A study is conducted on this model with magnet angle R varied from 0.25R to 1.5R, with 1.0R showing minimized values (Figures 4 and 5).
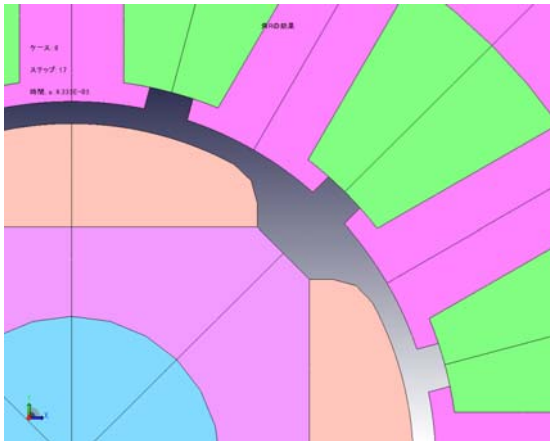

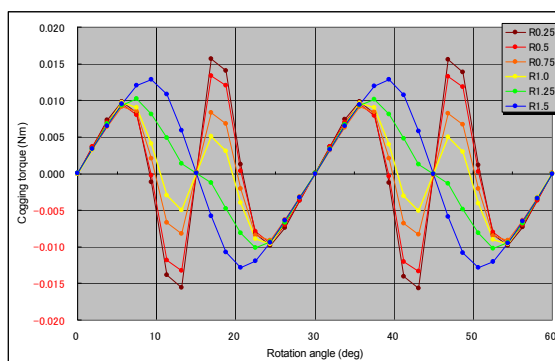Fig. 4 Differences in magnet angle R geometry

Fig. 5 Differences in cogging torque due to magnet angle R

FEM shows its true power in studies such as this kind of reduction of cogging torque. Only cogging torque reduction has been focused on here, but it can also help to determine geometry by evaluating the motor's induced voltage waveform and torque coefficient in parallel. Cogging torque analysis is a comparatively advanced-level use of FEA, so it is necessary to take adequate care of the modeling process, such as the symmetry of the mesh.

Optimized Design of the Rotor's Magnetic Circuit

Optimal use of material properties and efficiency in magnetic circuit design are called for to meet demands for smaller and lighter motors. If designs are made to allow some leeway in terms of magnetic saturation in the materials, it is possible to avoid a reduction in controllability due to increased iron loss and nonlinearity, but this leads to an increase in motor size. On the other hand, not providing this leeway means a reduction in the torque coefficient, higher loss, and worse controllability due to materials strain. For this reason, it is necessary to properly grasp the degree of magnetic saturation in order to design magnetic circuits that are not wasteful and not overloaded. This can be evaluated to a certain degree using the magnetic circuit method, but FEA is indispensable for designing to the limit. In particular, the magnetic circuit around the magnets in an IPM motor's rotor is extremely delicate, and has a large effect on the torque coefficient, iron loss, and torque variation.

Professor Yamazaki of Chiba Institute of Technology presented his results from optimized design of an IPM motor in his keynote address at the 2012 JMAG Users Conference (although unfortunately the study results used FEA developed by Professor Yamazaki himself). An improvement in performance was achieved by creating an appropriate slit near the rotor's air gap, but because in practice this type of measure means an increase in the length of the air gap and thus an increase in magnetic resistance, common sense seems to tell us that this should not contribute to an increase in motor performance. In fact, however, because the flow of the magnetic flux in the rotor became more ordered, iron loss was reduced thanks to suppression of higher-order components, and it was shown that the overall performance and efficiency of the motor was improved. In the future, it seems likely that this type of thinking about proper control of the magnetic flux flowing in the magnetic circuit will become more widespread. This sort

of idea is made possible thanks to the use of FEA.

Yamazaki Katsumi, Chiba Institute of Technology, "Loss analysis and shape optimization of rotating machines," presentation materials from JMAG Users Conference 2012. The above material can be accessed via the JMAG users-only webpage:

http://www.jmag-international.com/support/en/documentation/seminar_uw2012.html

Appropriate Magnet Geometry Design

It goes without saying these days that the rare earth magnets used in rare earth magnet motors are expensive. For this reason, designers want to get the maximum performance while using the minimum amount of them. Furthermore, these magnets are very delicate materials that are particularly susceptible to reduced magnetic properties due to raised temperatures, so adequate care must be taken of their useful temperature range so that they do not undergo thermal demagnetization. Also, field weakening controls are used to widen motors' output range, but since these weaken their field, there is great danger of demagnetization. Because it is difficult to restore a magnet's properties once it has undergone irreversible demagnetization, it is necessary to anticipate the surrounding temperature and tolerance for overloading in order to prevent demagnetization.

The following is an example of how motor characteristics change with variations in magnet width in an IPM motor. With the magnet thickness increased from 2.5 mm to 4 mm, attention is given to no-load induced voltage, torque, and the average magnetic flux density of the magnets (Fig. 6). An increase in thickness from 2.5 mm to 4 mm means a 60% increase in magnet volume, but induced voltage only sees an 8.3% increase. However, torque is increased 15.4%, with confirmation of this torque increase due to an armature reaction resisting the reverse magnetic field when the magnet is

made thicker. Further, the average magnetic flux density for the whole magnet increases 23.8%, from 0.52 T to 0.65 T (Fig. 7). These results tell us that the risk of demagnetization from heat and reverse magnetic field is reduced because the magnets' operating permeance is higher. This is to say, torque may not be much reduced with a reduction in magnet volume, but the risk of demagnetization becomes much higher.
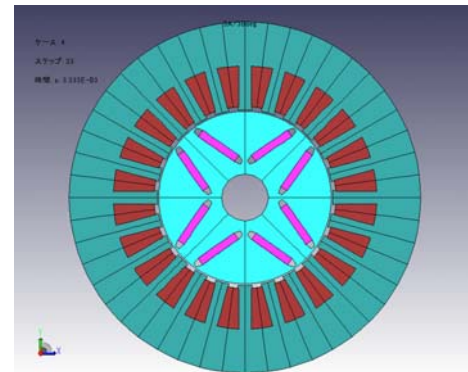
Fig. 6 Motor model used for magnet thickness study
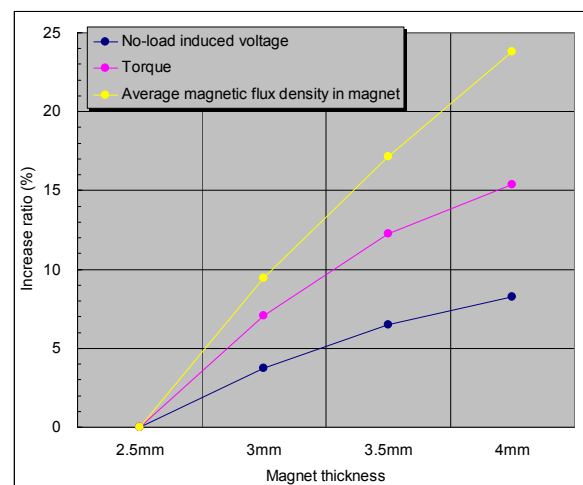
Fig. 7 Effects of properties due to magnet thickness

Neodymium sintered magnets are notorious for having relatively high electric conductivity, leading to eddy currents produced by slot harmonics and carrier harmonics that can cause heat generation, and therefore a rise in magnet temperature. As a workaround, divisions are often made in the magnets with insulating material in between, similar to the concept behind laminated cores. However, as the number of divisions increases,

production costs rise and magnetic properties fall, so it is important to design with the right number of divisions. The rotor and stator geometries strongly affect harmonic components, so a lot of factors have to be taken into account in order to determine the number of divisions. The number of magnet divisions and reductions in eddy currents are shown below (Figures 8 and 9).

Fig. 8 Motor model used for magnet eddy current loss study

No division 2 divisions 4 divisions 8 divisions (Unit: W/m3)

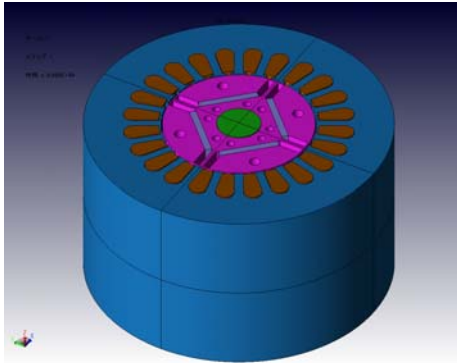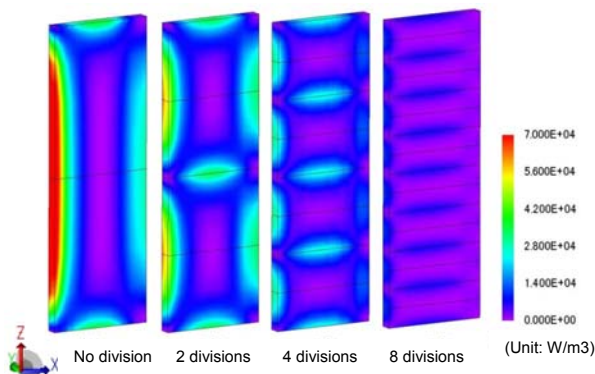Fig. 9 Reduction in eddy current loss due to magnet division

Maintaining Revolution Strength

Higher revolutions are essential for higher motor output. In terms of mechanical strength, rare earth sintered magnets are hard and brittle, so there is a danger of rupture if centrifugal force acts on them locally due to high-speed revolution. When the SPM motor in Figures 10 and 11 rotates at 10,000 rpm, the stress concentration generated in the magnet by centrifugal force is as shown. This model's structure has the core holding the corners of the magnet, and around 500 MPa of stress is produced in places. Since the compressive stress of rare earth magnets is supposed to be 1000

MPa, it can be seen that it has a safety factor of only 2.
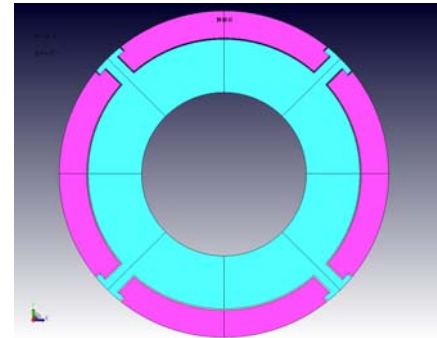
Fig. 10 Rotor model geometry for the SPM motor
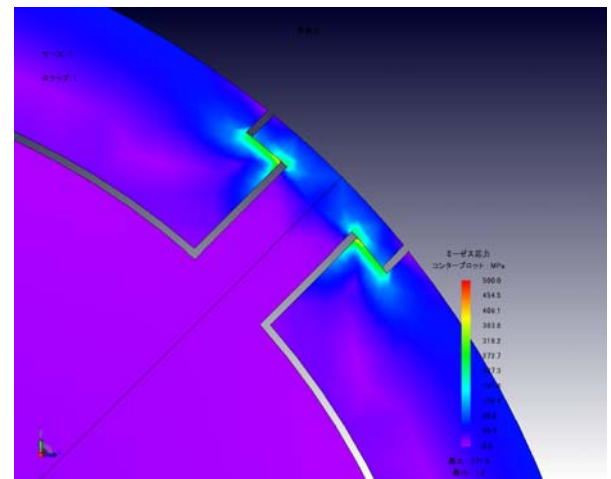
Fig. 11 Stress concentration generated in magnet during rotation

In IPM motors, where the magnets are embedded inside the rotor, the bridge part of the core supports the magnets' centrifugal force, and so concentrates the load in itself. From the standpoint of the magnetic circuit, it is better to design the bridge thinner to suppress leakage flux in the rotor, but if it is made too thin, it becomes unable to withstand the centrifugal force. Therefore, it is necessary to achieve a geometry that satisfies the needs of both the magnetic circuit and mechanical strength. To investigate these, the magnetic circuit is evaluated with magnetic field analysis, and the rotational mechanical strength is evaluated using structural analysis. The stress distributions produced in an IPM motor's bridge are shown in Figures 12 and 13.

Fig. 12 Rotor model geometry for the IPM motor

Fig. 13 Stress concentration generated

in bridge area during rotation

Adjusting Output Characteristics

The proportion of iron loss within total loss increases with higher rotation in motors, and high-output motors can have equal amounts of copper loss and iron loss. How to control iron loss is a major issue in motor design when it comes to improving efficiency. Iron loss can be reduced by lowering the operational magnetic flux density using magnetic pathways wi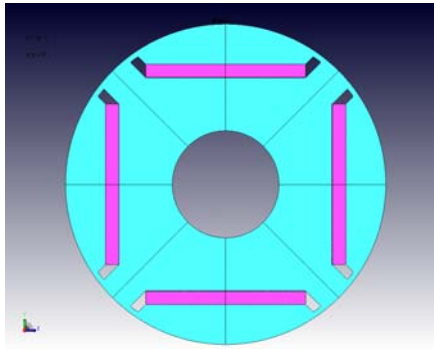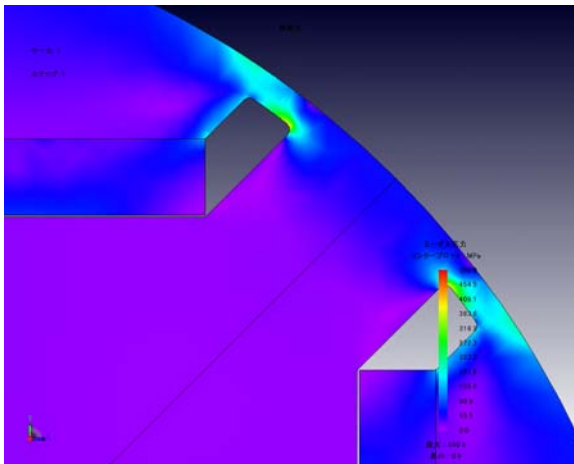th some leeway or by using materials with lower iron loss, but these lead to larger motor size and higher cost, and so cannot be adopted easily.

Because of this, what designers apply themselves to is seeking versatile designs that maintain the necessary maximum torque while keeping a high-level balance between cost, size, and output. They do this by focusing on high efficiency over the entire range, realizing high

efficiency in output range over longer operating times while ignoring efficiency in output range for shorter operating times.

The example in Fig. 14 uses efficiency maps to show the difference in output characteristics when magnets in the same stamped motor geometry are replaced with a Br1.0 T material from a Br1.2 T material, and the difference is made up for by changing the number of turns in the coils to maintain the same torque coefficient. There is no difference in maximum torque before and after the replacement because the torque coefficient is the same, but because of increased iron loss, the torque at 3000 rpm is reduced from 2.6 N·m to 2.1 N·m, meaning a large decrease in output. Similarly, the torque at 6000 rpm goes down from 1.5 N·m to 1.0 N·m. Still, this could be recommended in situations where a reduction in magnetic properties to lower costs is prioritized, because overall efficiency is realized at more than 90% over a wide range in both cases.
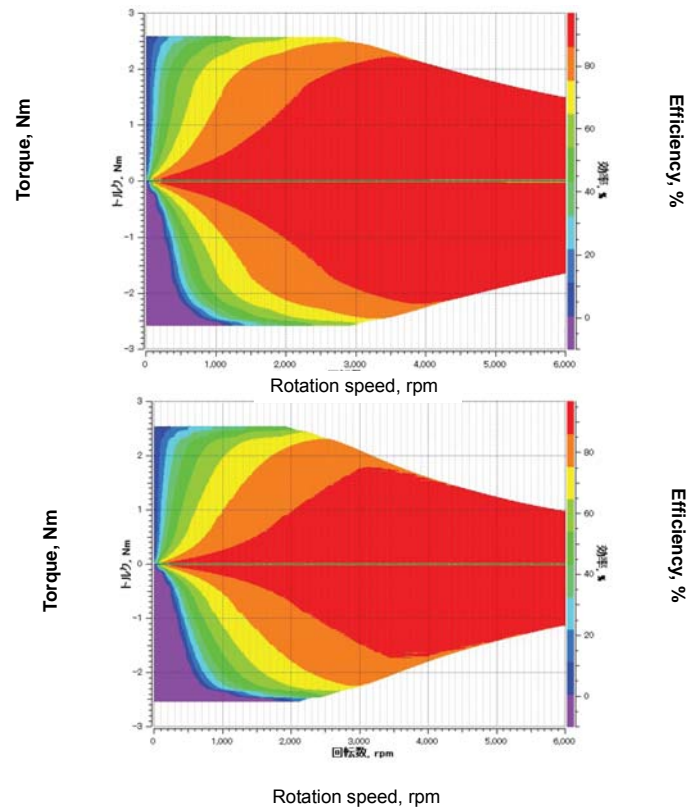

Fig. 14 Differences in output characteristics and efficiency

(Above: efficiency map of magnet Br1.2(T); Below: efficiency map

of magnet Br1.0(T))

Reducing Torque Variation

Torque variation, a cause of vibration and noise in motors, needs to be reduced in order to improve performance and quality. Torque variation is influenced not only by the motor's structure, but also by the phase current waveform, so analysis using FEA is essential.

Adding high harmonic components to the flowing current changes the torque waveform. Figures 15 and 16 show results from analysis of torque variation when the drive is by a sinusoidal-wave current and when third-order current has been added. It can be seen that there is a difference in the torque waveform when a third-order component of 0.5 A is superimposed and when 1.0 A is superimposed onto the fundamental 5 A wave. In this study, the torque variation was not reduced to zero, but it is possible to suppress a current waveform to zero by adjusting the amplitude and phase of each superimposed order.
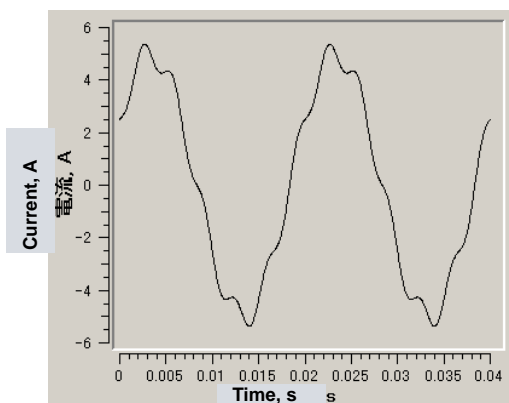
Fig. 15 Phase current waveform with superimposed 3rd order harmonic
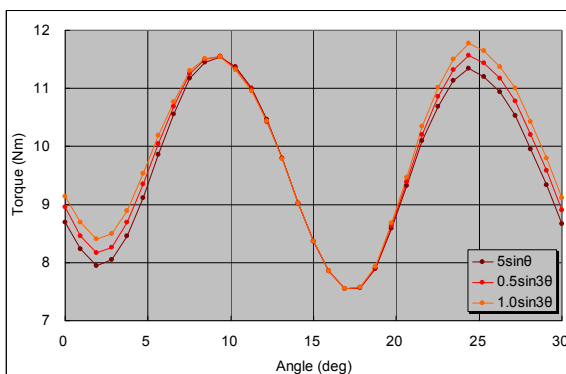
Fig. 16 Changes in torque variation due to flowing current

In Closing

Issue 2 of "Is FEA Effective in Motor Design?" has presented example uses for FEA during detailed design. The examples here have focused on evaluation issues for permanent magnet motors, but these apply similarly to inductance motors and SR motors.

I hope you have come to understand just how valuable using FEA can be for detailed motor design. It is nearly impossible to carry out this kind of study using only calculation by hand and experience.

Of course, I do not mean to say that just using FEA guarantees good design. Engineers who have never designed a motor, however well versed they are in how to operate FEA, will not be able to apply the results to their designs. What I hope you will take away from this is that engineers who are already familiar with motor design will be able to put FEA to use in creating even better designs.

In the next issue in this series, I plan to explain how even more detailed motor design can be accomplished using FEA. In particular, I will present how to take advantage of its potential to find the cause when problems arise in a real motor. J

(Yoshiyuki Sakashita)

Paper Introduction

Issue 3 For Those Planning to Start Analysis of Large Transformers

In this series, I would like to introduce various papers that present ways of using JMAG while performing electromagnetic field simulation. In Issue 3, I will introduce ten pieces (refer to [1] through [10] in Reference) of literature that will serve as a good reference for users who plan to start using electromagnetic field simulation for large transformers.

Introduction

I will be introducing some papers for you in this issue. I have been working on analysis technology for large transformers since last year. Here, I will present materials that will serve as a reference for people who, like me, are just getting started with analysis of large transformers, focusing on electromagnetic field analysis using the finite element method (FEM). Of course, the materials chosen here represent my perspective only, and I hope you will be understanding toward any seeming biases that I may have been unable to avoid.

What Should I Read First?

Large transformers, like other electric machines, have been around for more than a generation, and a wide variety of papers and other materials have accordingly been produced. The general trends can be found by looking at these, but there is such a large number that it is very difficult to know which to read first. I personally am interested in history, so I have chosen to take a long view of large transformers within the history of technology. Technological history is not a good way of learning about technical issues in detail, but I think it is a good approach for getting a broad overview of large

transformers in general.

Here, I would draw your attention to Reference [1]. The author has been involved in the development of large transformers at a large manufacturer for many years, and he discusses technological changes in large transformers over time from the standpoints of reliability, higher capacity, higher voltage, environmental issues, and accessory parts. He includes his own experiences such as an insulation breakdown incident when conducting the first 500kV test transmission in this country, and I think he makes it easy to read even for people who are not familiar with the field. It should be useful for gaining and systematizing basic knowledge.

I think this is an interesting way of seeing how the history of technology has led to today's technology, almost like watching a documentary film with its glimpses of human drama as opposed to a textbook full of specialist terminology and technical descriptions that may sometimes leave you staring blank-faced.

Materials on Large Transformer Analysis Using FEA

The purpose of a transformer is to provide a transformation ratio for its application, and large

transformers are those that handle tens of kV on their high-voltage side, tens of kA on their low-voltage side, and electrical power in the hundreds of MVA. Because of this, electromagnetic phenomena such as leakage flux, loss, magnetostriction and electrostriction vibration, and others, all caused by the high electric field and large current at this scale lead to technical problems.

I will introduce some materials dealing with these problems in sections for: loss analysis; electric field analysis; magnetostriction and electrostriction vibration analysis; and transient phenomena and electromagnetic force analysis.

1. Loss Analysis

One of the most promising uses for electromagnetic field FEM is the analysis of stray loss caused by leakage flux in large transformers (Fig. 1).

The large current produced on the low-voltage side generates leakage flux and stray loss inside the tank. The stray loss does not only have one fixed value, but can cause localized heat generation in the tank. Understanding and suppressing this stray loss is a design issue.

For stray loss analysis, it is necessary to include not only the core and coils, but also surrounding structural parts such as the tank and clamps, so the analysis model inevitably grows in scale. The issue becomes, at this point, what scale of analysis is possible?

In Reference [2], a 3-phase transformer is represented in a full model with around 11.5 million elements including the tank, shield, and clamps, and analyzed using a region partitioning method on the frequency region. Also, a thermal conduction analysis of heat caused by loss in the tank is carried out and compared with measured temperatures at the tank surface.

Stray loss analysis of a full transformer model focusing on local heat production can also be seen in Reference [3]. By running an FEA analysis on a nominal 240 MVA 3-phase transformer and comparing the loss density in various parts – tank, upper and lower clamps, cover plate (side plate) – it is found that stray loss is largest in the cover plate near the core.

As solving speed increases thanks to the spread of 64-bit machines and parallel processing technology, it is now becoming possible to run analysis at around the 10-million-element level at our own companies or our customers' companies. In the future, it is likely that even larger-scale electromagnetic field FEM will become possible.

Local heat generation is not only caused by stray loss in parts around the core, but also by iron loss in the core itself. Step lap construction, which has been increasingly employed since the 1980s, contributes to a reduction in iron loss, but at the same time it has led to problems with local heat generation at joints. It is unfeasible to directly reproduce the core in step lap construction because the analysis model becomes too large, but, because it is localized heat generation, an argument can be made for partial models focusing on joints.

In Reference [4], attention is given to step lap construction and overlap construction, and the local loss distribution in each is compared. A homogenization method of equivalent values is proposed from magnetic properties measurement, this is applied to transformer models, and iron loss values for each construction are compared.
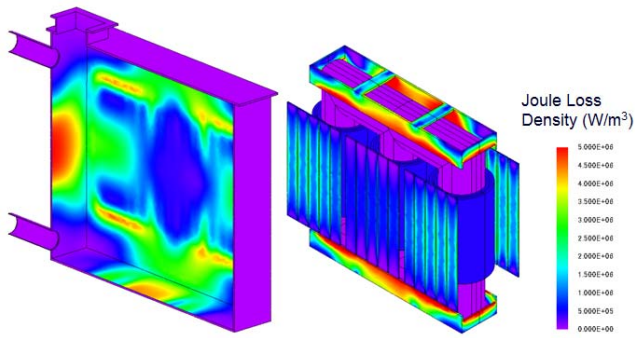
Fig. 1 Stray loss analysis of the tank and its interior

2. Electric Field Analysis

Adequate insulation measures are necessary on the high-voltage side because accidents in transformers are often caused by local insulation breakdown phenomena. It seems that evaluation using partial models focusing on transformer legs is common for evaluating insulation using electric field analysis, due to how localized and detailed the phenomena are (Fig. 2).

In Reference [5], attention is given to one leg of a 3-phase transformer, and the electric potential and electric field distribution are compared using steady state analysis by creating separate models for: the leg and coil adjacent to the tank wall; and the leg and coil adjacent to the next phase. Where electric field is expected to be high – the area around the pressboard and the start of the coil winding – modeling is done at the single-strand level (and changed to a bulk coil model partway through), and then differences in the electric field distribution in each region are compared. No clear difference is found between the two in this paper, but it is interesting to see what points designers pay attention to when using simulation to install insulation measures.

Reference [6] points out the importance of instantaneous electric field generation under drive and material nonlinear properties. An electric field analysis of the area near the pressboard, using the

pulse waveform, is carried out by solving continuity and Poisson equations in the time domain. Nonlinear properties of physical values are accurately handled in analyses of the time domain. The conductivity's dependence on the electric field is compared from the electric load distribution and electric field distribution in the analysis results. It is found that materials with nonlinear properties have a higher instantaneous electric field peak value than linear materials.
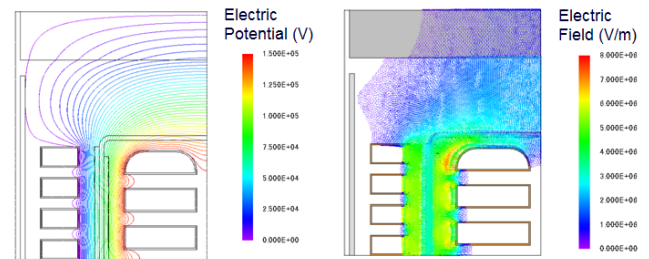
Fig. 2 Electric field analysis of pressboard

3. Magnetostriction and Vibration Analysis

Power generation facilities and substations generally have to be established a certain distance away from living environments, but with new residential areas being developed, borders between the two are frequently coming closer. There has been a lot of talk about the effects on the human body of the magnetic field generated by transmission lines, etc., but at this time no causal relationship has been established. Rather, there has been a greater demand for reduction of the more directly felt problem of low-frequency noise produced by substations, and more work has been done on vibration reduction and sound dampening in the transformers inside them.

Vibration phenomena produced in transformers are thought to be mainly due to magnetostriction and electromagnetic force, but quantitative evaluation using measurement by analysis has not been carried out much yet. In particular, because

the force caused by magnetostriction is not actually measured but rather estimated as an equivalent value from the amount of deformation, there is said to be room for disagreement about the applicability of that estimation. At present it is only at the stage of research including modeling, but it is now possible to find papers in which attempts are made to apply this to magnetostriction phenomena in transformers (Fig. 3).

In Reference [7], magnetostriction-magnetic flux density measurement results for the L and C directions of directional magnetic steel sheet are applied in a magnetic field analysis of a transformer core, and the amount of deformation and nodal force are calculated from the magnetic flux density distribution.

Reference [8] turns to the hysteresis properties (multivalent properties) of core magnetization properties and emphasizes differences by comparing them with the univalent properties of the past.
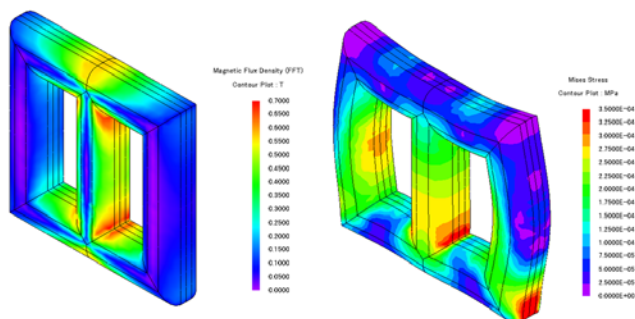

Fig. 3 Magnetic flux density and Mises stress in high harmonic components

4. Transient Phenomena and Electromagnetic Force Analysis

Excessive forces can be generated in the coils of large transformers from Lorentz force, and instantaneous geometry changes from this force are so large that they can be seen with the naked eye. Especially for transient phenomena, distortion harmonics other than the drive frequency can be generated due to nonlinearity in material properties. For this reason, it is expected that cases dealing with transient phenomena will be more common in future studies using analysis (Fig. 4).

In Reference [9], a formalization of magnetic field analysis in the time domain is applied to an analysis with an assumed short circuit in a transformer, and the Lorentz force distribution generated in the coils on the high-voltage side and the low-voltage side are evaluated along the direction of the leg. Further, the leakage flux from the shield and magnetic bypass plate and the reduction in stray loss due to this are confirmed.

Reference [10] handles transient phenomena using a formalization of magnetic field analysis in the time domain and tries verifying it with Team Problem 21^C and applying it to a 380 MVA single-phase transformer test machine.
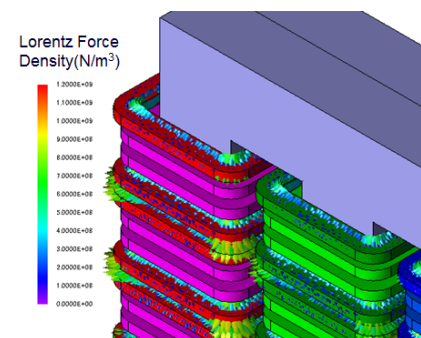
Fig. 4 Coil Lorentz force distribution analysis

In Closing

This article has introduced some materials that you may find useful in starting to use JMAG for analysis of large transformers. By also looking at the materials referenced by the papers introduced here, you can gain even more knowledge about large transformer analysis. I truly hope that the resources presented here will prove helpful for anyone planning to start electromagnetic field analysis of large transformers. J

(Takayuki Nishio)

Reference

[1] Toshiyuki Yanari, "History of Power Transformers in Japan and Description of Historical Materials," Survey Reports on the Systematization of Technologies No. 4 (March, 2004)

[2] Hiroshi Kanayama, Shuji Asakawa, Shin-ichiro Sugimoto, "A Large Scale Eddy Current-Thermal Analysis for a Transformer Tank" IEEJ Transactions on Power and Energy B128 (2)（2008）

[3] S. Waik, P. Drzymala, H. Welfle, "3D Computer Field Model of Power Transformer-Magnetic Field and Power Losses Computation" ICEM（2010）

[4] Koji Fujiwara, Yoshifumi Takakura, Yasuhito Takahashi, *et. al.*, "Iron Loss Analysis of the Wound-Core Transformer Considering Core Joint Configuration" The Institute of Electrical Engineers of Japan Research Materials SA, Static Machines Research Society 2011(63), 43-48,（2011）

[5] Shan Tao, Zhang Peihong, "Calculation of 3D Electric Field at the End Insulation of Transformer," 2011 The 6th International Forum on Strategic Technology

460-463 （2011）

[6] Gang Liu, Lin Li, Feng Ji, Wenping Li, Youliang Sun, Bo Li, and Jinzhong Li "Analysis of Transient Electric Field and Charge Density of Converter Transformer Under Polarity Reversal Voltage" IEEE Tran. on Magn., vol. 48, no. 2, 275-278 （2012）

[7] Wataru Kitagawa, Yoshiyuki Ishihara, *et. al.*, "Analysis of Structural Deformation and Vibration of a Transformer Core by using Magnetic Property of Magnetostriction," The Transactions of the Institute of Electrical Engineers of Japan. B, A Publication of Power and Energy Society SA-06　76-9453-58 （2006）

[8] Tom Hilgert, Lieven Vandevelde, and Jan Melkebeek, "Comparison of Magnetostriction Models for Use in Calculations of Vibrations in Magnetic Cores" IEEE Tran. on Magn., vol. 44, no.6, 874-877 （2008）

[9] S. L. Ho, Y. Li, H. C. Wong, S. H. Wang, and R. Y. Tang "Numerical Simulation of Transient Force and Eddy Current Loss in a 720-MVA Power Transformer" IEEE Tran. on Magn., vol. 40, no.2, 687-690,（2004）

[10] Zhanxin Zhu, Dexin Xie, Gang Wang, and Xiuke Yan "Computation of 3-D Magnetic Leakage Field and Stray Losses in Large Power Transformer" IEEE Tran. on Magn., vol. 48, no.2, 739-742 （2012）

Fully Mastering JMAG

From the FAQ Files

Traditionally, JMAG has been used mainly by technicians specializing in electrical systems, but in recent years there have been more opportunities for mechanical designers and others to use it for electromagnetic designs outside of their own field. There are probably quite a few among those who have made the transition to this unfamiliar tool who worry about how they should use it to perform better analyses.

This section of the Newsletter deals with questions that we receive most often in order to help people who are having similar kinds of problems, and make JMAG a more user-friendly tool.

The questions here cover a wide range of topics, such as "Operation Methods", "Analysis Techniques", and "Troubleshooting". Please take a look at the topics that interest you.

OPERATION METHODS FAQ-887

Q1. Can I use my analysis files from JMAG-Studio in JMAG-Designer?

A1. Yes, you can use them in the JCF file format.

The file formats that were supported in JMAG-Studio listed below cannot be used directly in JMAG-Designer, but they can be used in JMAG-Designer after converting them to the JCF file format.

· Project files (*.jsp) saved in JMAG-Studio file format.

· Save data file (*.ssv)

· Solver data file (no extension)

A JCF file can be imported by drag-and-dropping it on the JMAG-Designer screen.

Circuit files (*.cct) and point sequence files (*.pa) can be used by importing them.

Procedures to import the files are described below.

【Circuit file (*.cct) 】

1) Open the Circuit Editor window.

2) Select [Import Circuit] from the [File] menu.

3) Select [JMAG CCT Files (*.cct)] under [File type] and open any circuit file (*.cct).

【Point sequence file (*.pa)】

1) Select the setting items to be used for the point sequence file and open the Edit Point Sequence dialog box.

2) Right-click anywhere on the Edit Point Sequence dialog box and select [Import] from the shortcut menu.

3) Select [Table file (*.pa)] in the [File type] and open any table file (*.pa).

【Other resources】

Please see the following Help items for more information regarding the file formats that can be used in JMAG-Designer.

JMAG-Designer Help > Basic Operations > Tool Bar Buttons > File

Q2. Does JMAG-Designer include a function similar to the [Region Relation] function in JMAG-Studio?

I want to create a mesh model with symmetry in order to accurately obtain the cogging torque in a motor. In JMAG-Studio, the [Region Relation] function was available to create a mesh with symmetry or periodicity. How can I do this in JMAG-Designer?

A2. Yes, JMAG-Designer has an equivalent function.

In JMAG-Designer, the equivalent function is called [Part Relation].
Define the relationships between parts by following the steps below before creating a mesh.

1) Right-click [Mesh] under [Study] in [Project Manager] to generate the mesh. The shortcut menu is displayed.
2) Select [Part Relation].
3) Click on the [Parent Part] box, and then select a part in the graphics window to use as a parent part.
4) Click on the [Copied Parts] or [Mirror Copied Parts] box, and then select a part to use as a child part in the graphics window.
5) If parts with a parent / child relationship set have rotational periodicity, select [Rotation] under [Copy Type].
6) Click [OK].

The relationship between parts set in the abovementioned procedure is accounted for when creating a mesh.

Also, the [Rotation Periodic Mesh] function is useful when creating a mesh model with symmetry for a rotating machine model.
This function makes it possible to create a mesh with symmetry in the vicinity of the gap for a model that has rotational periodicity.

In JMAG-Designer not only the mesh generation function is still available, but also many functions to generate a more flexible mesh have been newly added.
These functions are very useful, so be sure to give them a try.

【Newly added mesh generation functions in JMAG-Designer】
· Element size specifications for edges and vertices: adjust mesh density to the specified element size.

- Layered mesh: generate a layered mesh parallel to the specified solid face.

- Thin shell mesh: generate a mesh using a shell.

- Defeaturing: generate a mesh after removing fillets or chamfers.

- Morphing: directly change the geometry of the mesh model.

- Honeycomb mesh: fill in a mesh in the air region while maintaining the existing mesh.

- Mesh redivision: redivide the mesh in a localized region of the mesh model.

【Other resources】

Please see the following Help items for more information regarding mesh creation in JMAG-Designer.

JMAG-Designer Help > Functions of Analysis > Mesh > Mesh

OPERATION METHODS FAQ-898

Q3. Can I use my subroutines from JMAG-Studio in JMAG-Designer?

A3. Subroutines from magnetic field analysis and thermal analysis can be used directly, but subroutines from other modules need to be recompiled.

The API of subroutines from magnetic field analysis and thermal analysis are in C, so they can be used in JMAG-Designer as they are.

Iron loss, magnetization, and electric field subroutines need to be recompiled.

Subroutine modules (DLLs) that can be used directly in JMAG-Designer:

- Magnetic field analysis

- Thermal analysis

Subroutine modules that need to be recompiled:

- Iron loss analysis

- Magnetization analysis

- Electric field analysis

The compilation environment is different from JMAG-Studio's, so please be careful.

JMAG-Designer's compilation environment is as follows:

Microsoft Visual Studio 2010

Intel Visual Fortran Composer XE 2011 for Windows* (Intel Fortran Compiler 12.1)

OPERATION METHODS FAQ-899

Q4. Can I use my scripts from JMAG-Studio in JMAG-Designer?

A4. They cannot be used. The script language is different, so you will need to create them again.

The script languages for JMAG-Studio and JMAG-Designer are different. Because of this, scripts that had been used in JMAG-Studio unfortunately cannot be used in JMAG-Designer. We apologize for the trouble, but you will need to create your scripts again.

However, it is not at all difficult to create scripts in JMAG-Designer. There is an automatic recording function, so the procedures you want to create can easily be converted into scripts. Also, scripts in JMAG-Studio use a unique language, so they have limited utility for numerical calculation, linking to Microsoft Excel, and other uses, but JMAG-Designer uses general-purpose script languages and so has a high degree of freedom in code syntax, allowing a wide range of processing. JMAG-Designer supports VBScript, Jscript, and Python.

If the script you were using in JMAG-Studio was for parametric analysis, it is easy to carry out parametric analysis using JMAG-Designer's case control function. The case control function can be used for not only conditions settings, but also for design variables such as geometry parameters and mesh parameters. Also, simple optimization processing using objective functions is possible.

【Other resources】

Please see the following materials for more information regarding differences in scripts between JMAG-Designer and JMAG-Studio.

http://www.jmag-international.com/support/en/seminar/pdf/uc2011_30_eng.pdf

Please see the following Help items for more information regarding case control functions and optimization functions in JMAG-Designer.

JMAG-Designer Help > Analysis > Parametric Analysis

JMAG-Designer Help > Analysis > Optimization

OPERATION METHODS FAQ-900

Q5. How can I perform a Fourier transform on a history graph?

A5. Use the Fourier Transform function in the Graph Manager.

Table data such as time series data and section graphs obtained in analysis can be edited and managed as table sets in the Graph Manager. Fourier transform processing is also done via the Graph Manager. The exact procedure is as follows:

For example, if Fourier transform is desired for a torque waveform:

1) Set the Torque condition and carry out a Magnetic Field / Transient Response analysis.

2) When the analysis if finished, open the Graph Manager. Select [Graph Manager] under the [Tools] menu.

3) Find the torque data set in the data set list.

4) Click the [Transform] button in the Graph Manager dialog and choose [Fourier Transform].

5) Enter the [Output Type] and [Range], and then click [OK].

6) The Fourier transform data set is added to the list of graphs in the lower half of the Graph Manager.

The Graph Manager can show not only analysis results data, but also any data sets such as CSV files and point sequence files (*.pa).

【Other resources】

Please see the following Help items for more information regarding the Graph Manager function in JMAG-Designer.

JMAG-Designer Help > Result Display > Graph Manager

OPERATION METHODS FAQ-901

Q6. Can I confirm analysis results at the single-element level?

A6. Yes, you can confirm results per element.

The Table function can be used to confirm results per element. The exact procedure is as follows:

1) Set the selection mode to [Select Element]. Choose [Select Element] from the tool buttons.

2) In the model display window, select the element for which you want to confirm results. You can select multiple elements by holding the [Shift] or [Ctrl] key on your keyboard.

3) Display the right-click menu on the model display window, and select [Show Table].

4) Specify the physical quantity and step number you want to confirm and click [OK].

JMAG-Designer has a wide variety of collection and tabulation functions for distribution amounts at the element level, and these are listed below. Tabulation work that was previously done by outputting values and working by hand can now be accomplished automatically.

· Create FFT Calculation

Runs a fast Fourier transform on distribution amounts output by transient response analysis.

Distributions can be confirmed per frequency component.

· Difference Calculation

Calculates the difference or ratio of the results from two cases.

For example, variations in the magnetic flux density distribution when conditions or materials are changed can be confirmed in a contour plot.

· Add Part Calculation

Calculates the total sum of the physical amount for the selected part (faces, edges) or the maximum value and displays a table.

For example, the amount of current flowing through any cross-section can be obtained, or a history graph of maximum temperatures in a model can be created.

【Other resources】

Please see the following Help items for more information regarding table functions in JMAG-Designer.

JMAG-Designer Help > Result Display > Tables > Displaying a Table

Please see the following Help items for more information regarding calculation processes for physical quantities in JMAG-Designer.

JMAG-Designer Help > Result Display > Calculation Process

JMAG-Designer Help > Result Display > Tables > Adding Calculation for Parts, Faces, and Edges

Technical FAQ on the Web

The Technical-FAQs section of the JMAG webpage has been redesigned as of March 29. More topics have been added, and categories have been reconsidered to make it easier for you to find answers to your questions. Please take a look at the new, more powerful Technical-FAQs when you have a chance.

URL: http://www.jmag-international.com/support/en/faq/ (user verification required)

The technical FAQ is a collection of actual questions from our clients, so you might discover some new ways to use JMAG if you go through them. We also update the FAQ on our homepage regularly, and we hope that you can use them along with the JMAG Newsletter to help streamline your analysis operations. Please don't hesitate to use JMAG technical support if you have any questions when using JMAG. We hope you will fully master JMAG-Designer!

(Takashi Kondo）

Fully Mastering JMAG
Issue 8 Understanding Conditions from A to Z

Continuing from last issue, I would like to introduce convenient functions for some of the conditions in JMAG's magnetic field analysis. I hope you will find this useful for finding new conditions and to remind yourself of various functions. In this issue, I will present functions to make complicated analyses easy, such as conditions for coupled analysis within JMAG and linked analysis with other software, as well as solver parameters such as nonlinear and ICCG. I hope you will aim to fully master JMAG and make your work more efficient.

Overview

In this issue's A to Z, I will present conditions used for linking JMAG magnetic field analysis with other kinds of analysis, and also with other software. I will also present conditions for easily managing complex modeling and analysis properties that govern general analysis settings.

Linking

JMAG-Designer has functions for thermal and structural analysis in addition to magnetic field analysis. It is particularly robust for linking with structural and thermal analysis software such as Abaqus and Virtual.Lab, and also with the HILS ECU evaluation system (Fig. 1). Here, I will introduce necessary functions for linked analysis with these, and also for coupled analysis within JMAG.
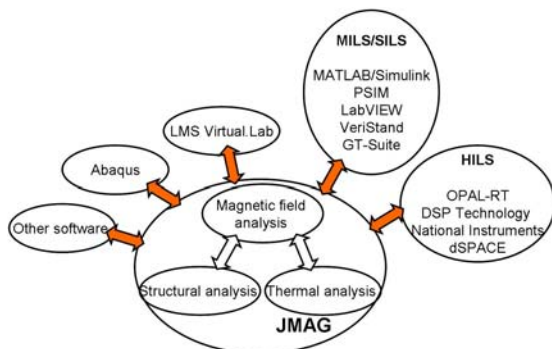

Fig. 1 JMAG and surrounding software

(HILS is a company name. Only software titles relevant are included here)

Partial Model

This condition is for accurately transferring the temperature distribution to a magnetic field analysis when making a partial thermal analysis model with periodicity or symmetry for coupled thermal and magnetic field analysis.

It is possible to use a partial model when a model has periodicity or symmetry by simplifying the thermal structure. However, a full model may be necessary for magnetic field analysis depending on the core geometry or the relationship between the number of poles and number of slots in a rotating machine (Fig. 2). In such cases, this condition can be used to accurately transfer the temperatures generated in the thermal analysis to the magnetic field analysis.
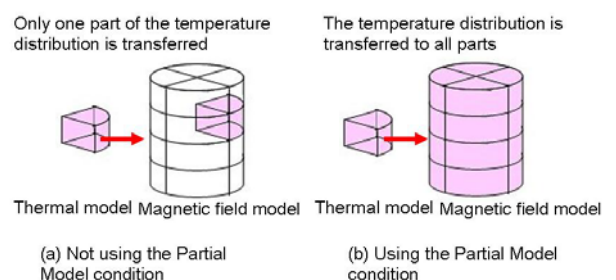

Fig. 2 Transferring temperatures from thermal analysis to magnetic field analysis

External Circuit Link

This condition is set when linking JMAG and SILS software.

Electric machine drive is becoming increasingly complex, and in order to predict machine performance, the link between electromagnetic field analysis and drive circuits cannot be broken. In such cases, it is effective to analyze the drive circuit with MATLAB/Simulink or PSIM and do electromagnetic field analysis in JMAG.

For the External Circuit Link condition, choose the terminals you want to display in the external circuit simulator (Simulink, PSIM, etc.) (Fig. 3). As examples, you might think of the torque used for control in an external circuit and the electric potential, etc. for drive in JMAG. Linked analysis is achieved by connecting the connection terminals that appear from JMAG's block with another block in the external circuit simulator.

I would also like you to know about the further evolution of this condition in the JMAG-RT system for faster linked analysis. This is recommended when linking with SILS, MILS, and HILS systems. Settings are done via the JMAG-RT Library Manager.

Here is one example use. Line-start is one startup method for induction motors. It is often seen as a problem for the startup current to grow too large, but it is not possible to estimate it with electromagnetic field analysis alone due to the complexity of the drive circuit. With this condition, it becomes possible to link MATLAB/Simulink and JMAG (Fig. 4.) to evaluate the current (Fig. 5).
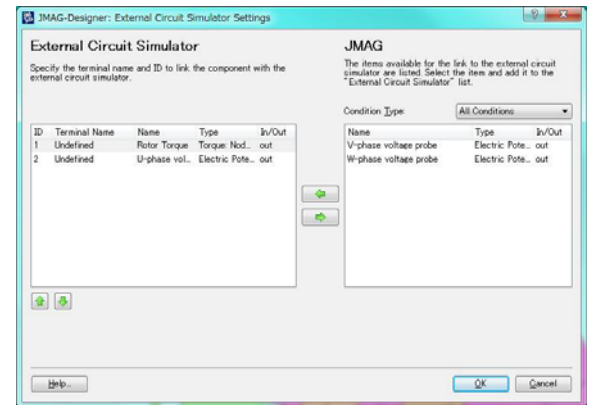

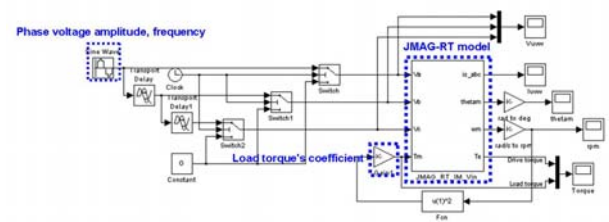Fig. 3 External Circuit Link condition panel
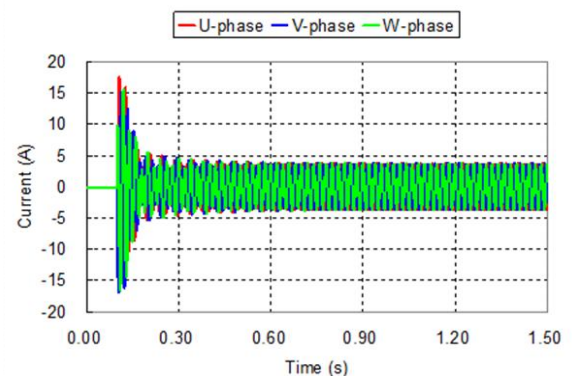

Fig. 4 MATLAB/Simulink setting diagram

Fig. 5 Induction motor startup current evaluation

Frozen Permeability

This makes it possible to use past JMAG electromagnetic field analysis results to identify material properties in subsequent electromagnetic field analyses. For example, it is used in cases like the following:

- To separate a rotating machine's torque into magnet torque and reluctance torque.
- To precisely calculate the dynamic inductance with DC superposed in a reactor, etc.

Here I will discuss separating a rotating machine's torque. First, a normal electromagnetic field analysis is run on the rotating machine (hereafter called Analysis A). Next, an analysis is run of the magnetomotive force for the magnets only (hereafter called Analysis B). Frozen Permeability is set in Analysis B, with the results file from Analysis A specified. This way, material operating points from Analysis A are used in Analysis B.

If the results obtained from Analysis B are defined as the magnet torque, the reluctance torque is obtained by subtracting Analysis B's torque from Analysis A's (Fig. 6). An exact torque separation is difficult, but the torque can be separated here by assuming that the operating point does not change.
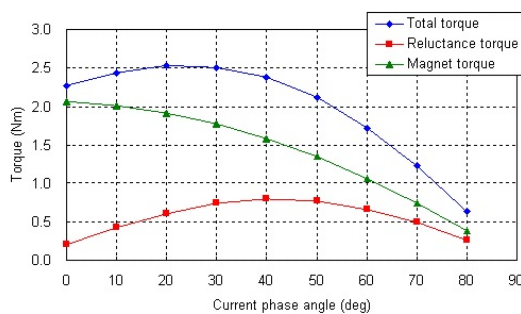

Fig. 6 Torque separation results for a rotating machine

Stress Distribution

This condition is used to display the deterioration of magnetic properties in magnetic steel sheet caused by stress.

Magnetic steel sheet's magnetic properties are known to deteriorate due to stress. This leads to concerns about increased loss. With JMAG's Stress Distribution condition, it is possible to set the stress for each part and replicate the materials' deterioration. For coupled magnetic field - structural analysis, the stress distribution obtained in the structural analysis can also be represented in the magnetic field analysis.

This can also be used while linking with other software. For example, in the example below,

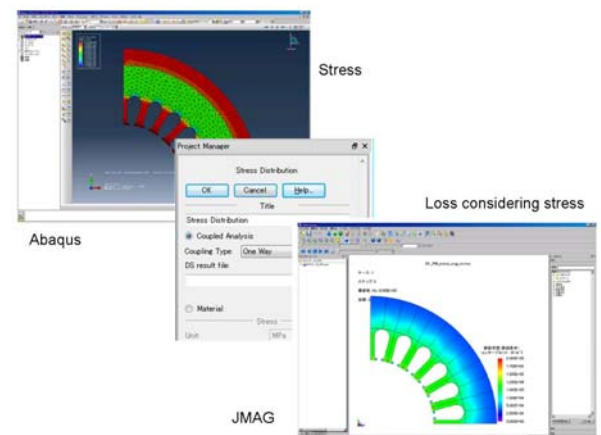stress distribution results obtained in Abaqus are represented in JMAG for an iron loss calculation (Fig. 7).

Fig. 7 Iron loss calculation accounting for stress (linked to Abaqus)

Displacement

Magnetic circuits also change when a geometry is changed. The Displacement condition is for carrying out linked analyses in JMAG and Abaqus that take geometry changes into account.

For example, when a billet is subjected to compression, it is squashed and its geometry changes as seen below. Its magnetic properties may also deteriorate due to a rise in temperature. Magnetic field analysis considering these factors can be done by using this condition (Fig. 8).

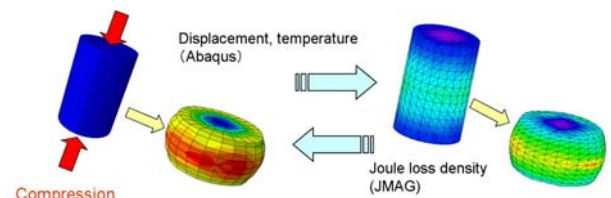The Displacement function can also be used for coupled magnetic field – structural analysis within JMAG.

Fig. 8 JMAG-Abaqus linked analysis using the Displacement condition

Reusing Demagnetization

Magnets that have already undergone irreversible demagnetization may be used in subsequent analyses. When using magnets that have already been used without being remagnetized, such as when reusing the rotor of a rotating machine, etc., there may be concerns about the effects of demagnetization caused during earlier operation. In JMAG, a 2-stage analysis can be done for a performance estimate in these cases.

In the example below, the first stage is an analysis of the rotating machine during operation. In the second stage analysis, the results from the first stage are set in the Reusing Demagnetization condition to express the demagnetized state.

The reduction in torque during reuse, due to the effects of irreversible demagnetization caused by the heat generated in the first stage, is estimated using analysis (Fig. 9).
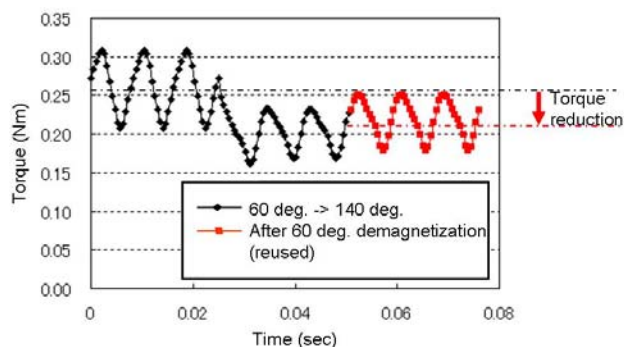
Fig. 9 Torque reduction from irreversible

demagnetization

Modeling

There are probably many who think that complicated settings are needed to do high-precision analysis of complex phenomena. But with JMAG, complex analysis can be easily achieved through some tricks in the modeling process. I will now introduce some conditions that will allow you to use these tricks.

External Field

This condition is used for analysis of objects inside a uniform magnetic field. Normally, in order to produce a magnetic field in space, it is necessary to produce magnetomotive force by creating a coil as a finite element model and setting a Current condition, or by linking to a circuit. By using this condition, a uniform magnetic field can be generated without modeling a coil, therefore reducing modeling time.

For example, this is an effective function for evaluating the performance of a shield placed in a uniform magnetic field as shown in Fig. 10. It can be seen that in this model, the magnetic flux density in the area around the shield is high in the red boxes and low near the blue boxes. Shields are usually made of thin parts, and because JMAG also has functions for automatically creating a thin shell mesh, using these together is convenient.
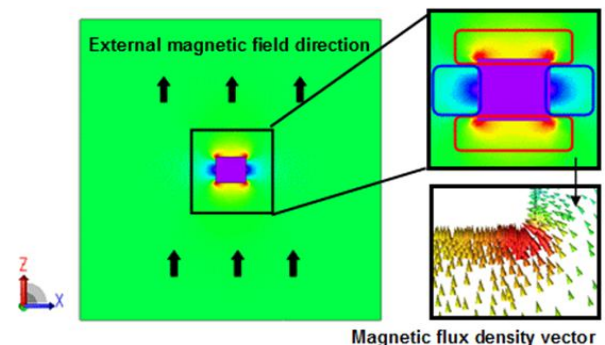
Fig. 10 Magnetic flux density distribution around a

shield

Gap

This condition is for setting very thin magnetic air gaps without generating a mesh.

For example, when a core is constructed with multiple core divisions, thin air gaps are created between them. Because air gaps cause strong magnetic resistance, it is preferable to generate a mesh for them in order to be sure of accurate analysis. However, the number of mesh elements

will become much greater if the mesh is created for the thin air gaps, and more calculation time will be required. The ICCG convergence may also deteriorate due to the mesh becoming too thin.

With this function, this magnetic resistance can be expressed without the need to generate a mesh in the thin air gaps.

In the graph below, this condition is used to evaluate coil magnetic flux while varying the gap width of a reactor's center gap from 0.1 mm to 2 mm without generating a mesh (Fig. 11). Magnetic flux evaluation is made easy by using Case Control in JMAG-Designer.
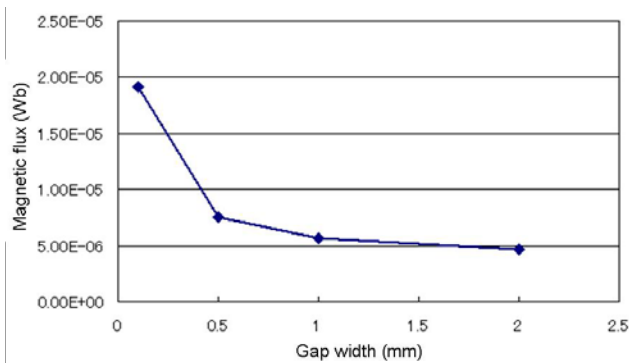

Fig. 11 Relationship between gap width and magnetic flux

Insulation

Similar to the Gap condition, this condition is for expressing electric insulation without modeling the air gaps built into cores or magnets.

For example, magnets are sometimes divided to reduce eddy currents, but it can require a lot of work to create another model every time the number of divisions is changed if mesh is generated in the gaps.

The electric insulation can be modeled simply by setting this condition to the division faces or by checking the Insulation check box for the part. Precise evaluation of eddy currents is done easily without the need to change the mesh (Fig. 12).
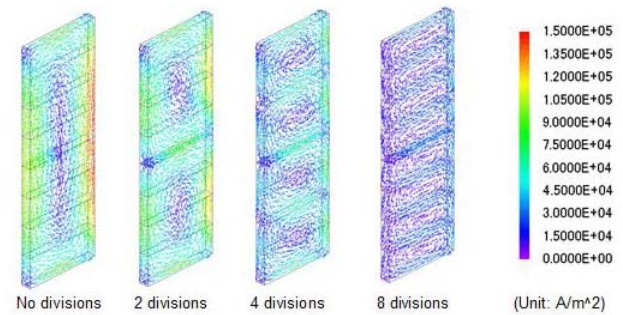

Fig. 12 Evaluation of eddy current reduction due to magnet division

Section

This function makes it possible to automatically extract a 2D cross-section from a 3D model for analysis.

2D analysis is considered to provide adequate precision when the shaft length is long compared to the radius. For example, looking at a rotating machine's torque history, there is only a difference of a few percent between 3D and 2D analysis (Fig. 13). Analysis could be done by first obtaining a rough estimation in 2D analysis and then running 3D analysis when seeking more detailed precision. If this were the case, it would be a lot of work to make a separate model just for 2D analysis, but a 2D model can be automatically output from a 3D solid model using JMAG's Section condition (Fig. 14). The analysis could be done immediately without the need to set materials, conditions, etc. again.
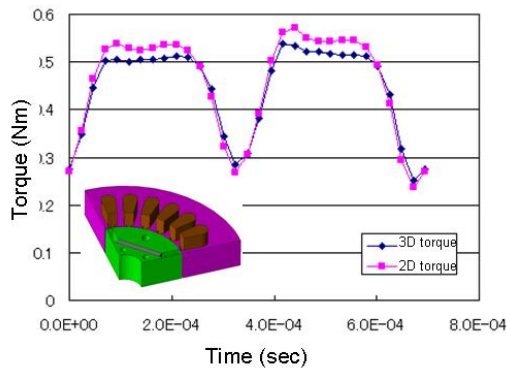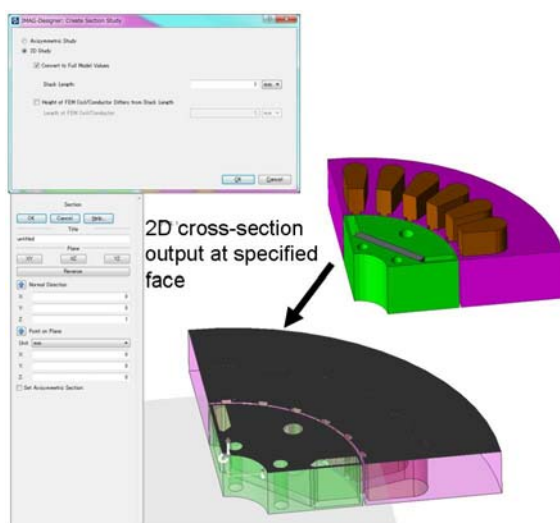
Fig. 13 Torque history (comparison of 2D and 3D)

Fig. 14 Cross-section analysis settings

Output

In addition to physical quantities such as torque and magnetic flux density, for which results are commonly evaluated, JMAG's magnetic field analysis can also output physical quantities with more specialized uses. Two of these physical quantities are presented below.

Magnetostriction

This is used for evaluating magnetic strain. Vibration caused by strain is particularly hard to ignore in large transformers, so it is helpful to be able to estimate it using analysis.

JMAG's Magnetostriction condition checks the magnetic field distribution obtained in magnetic field

analysis against the magnetic flux density - strain properties, and converts it to magnetostriction. Vibration analysis is possible using this as the source of vibration (Fig. 15).
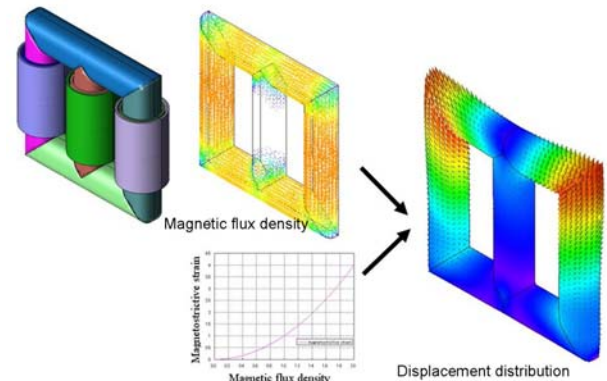

Fig. 15 Transformer using magnetostriction properties and magnetic flux density

Partial Inductance

This condition is used to output self- and mutual inductance generated in selected parts as a matrix model.

For example, inductance in the wiring seen in busbars inside inverters, etc. varies widely depending on the geometry and spatial arrangements. Too large of an inductance can lead to surges during switching, so this must be improved.

However, actually measuring the inductance can only yield a value for the entire measurement target. This means that you cannot tell where in the wiring most of the inductance is. But by using this condition, you can see at a glance which areas to improve because the self- and mutual inductance is calculated in a matrix model for parts that have already been separated (Fig. 16).

In the example below, the surge voltage evaluated by the circuit simulator is reduced more than 10% by changing the geometry from the initial proposal based on examination of the inductance matrix of the busbar parts (Fig. 17).
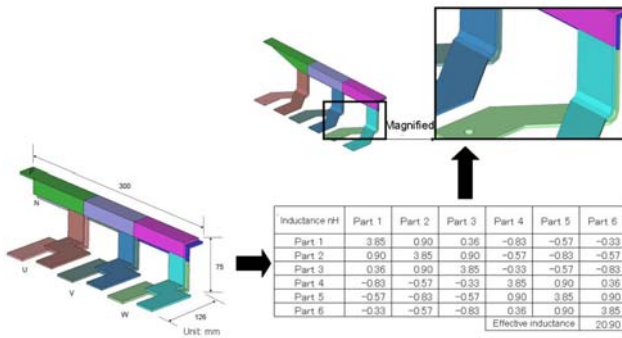
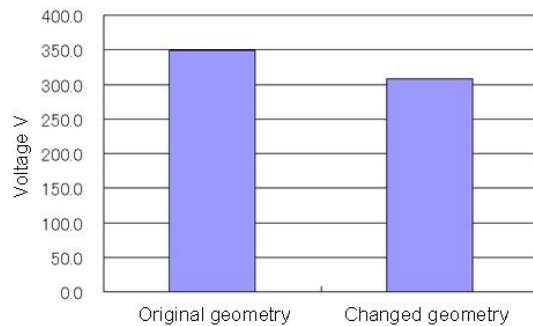Fig. 16 Geometry improvement based on study of the inductance matrix

Fig. 17 Surge voltage reduction

Study Properties

Parameter tuning for time step settings, conversion, and iterative methods is done under Study Properties in JMAG-Designer.

Step

This contains settings for time steps. The number of steps, division method, end time, etc. are all set here.

Conversion

Periodic boundaries are often used in magnetic field analysis, and this converts those results to a full model for output. This is recommended because it allows results to be compared directly with actual measurements.

Circuit

This converts the parameters set to a circuit. It is effective when a partial model is being used.

With conversion, values such as vibration, resistance, and inductance for the power source specified in an analysis can be set to a full model.

Solver

This is where to handle: settings for Parallel Computing; Steady-State Approximate Transient Analysis that is run to make steadying faster in terms of time; and settings for Time Periodic Explicit Error Correction functions.

Under Parallel Computing, Shared Memory Multiprocessing (SMP) or Distributed Memory Multiprocessing (DMP) can be selected. Also, a GPU can be employed to increase speed.

Steady-State Approximate Transient Analysis is used when no delay is needed for starting up current, etc. generated by inductance effects in applications where there are no magnets (stationary devices, induction machines, etc.).

Time Periodic Explicit Error Correction is used for the same kinds of purposes, but can be used in PM motors, which have magnets (Fig. 18). It is also effective for rapid steadying of superimposed conditions such as switching transformers.
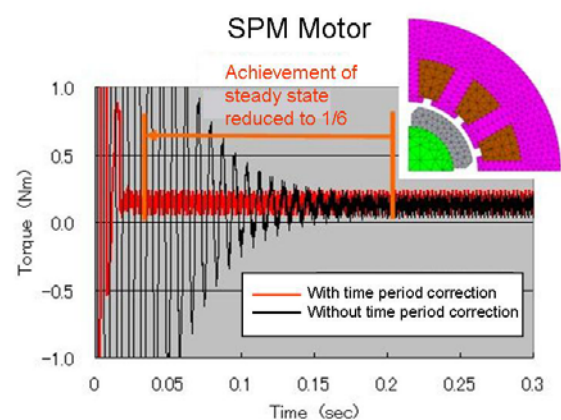

Fig. 18 SPM motor torque history

ICCG and Nonlinear

Iterative methods are used for solution-finding by JMAG solvers. Robust high-speed ICCG is used by the linear solver, and the Newton-Raphson method is used as a nonlinear iterative method. Convergence parameters for each of these are set here.

When convergence is slow in ICCG, setting the Acceleration Coefficient slightly higher may improve the convergence. Likewise, changing the default threshold value of nonlinear iterations from 1e-3 to around 1e-4 can help to increase precision when using nonlinear materials. There may not be many people who are even aware of these parameters, but I think it is a good idea to adjust parameters a little and see how sensitive calculation time and precision is to them, especially for those who are unsure whether their own analysis models are providing sufficiently fast and precise results.

In Closing

Over the past two issues, we have presented a number of conditions used in magnetic field analysis in JMAG. I hope you have found some that you will be able to use in your own analyses. I also hope that you have gained more detailed knowledge of the conditions you already use on a regular basis.

JMAG's functions will continue to grow in the future. New conditions are often presented at our seminars and other events. It is our hope that you will be able to fully master all of these conditions.

(Kazuki Semba)

Event Information

Information on the JMAG Users Conference in Germany

Building on last year's success, countries around the world will play host to a JMAG Users Conference 2013. In this issue, we are pleased to announce one in Germany.

JMAG Users Conferences are programs that emphasize engineers communicating with each other. They are an excellent chance to collect information on ways that electromagnetic field analysis is being used and other topics, so please attend if you are able.

JMAG Users Conference in Germany and JMAG Technical Day
Conference Outline

Host: Powersys Solutions

Dates: Wednesday, April 10 - Thursday, April 11, 2013

Venue: Steigenberger Airport Hotel Frankfurt (Frankfurt, Germany)

URL: http://www.powersys-solutions.com/JMAG_UC/

Program (Day 2)

09:45	**Investigation of Proximity Losses in a Permanent Magnet Machine for electric vehicles** David Bauer, Robert Bosch GmbH, Germany.
11:00	**Development of electric motors in automotive applications using JMAG Software** Mohamed Hadjali, Nidec Motors & Actuators, Germany.
11:40	**Enhanced Simulation Quality for Electric Drives in Hardware-in-the-Loop Applications** Bjoern Bobe & Matthias Deter, dSPACE GmbH, Germany.
14:00	**Axial flux machine simulation with JMAG** Dr.-Ing. Bogdan Funieru for Institute for Electrical Energy Conversion, Technische Universität Darmstadt, Germany.
14:40	**Optimizing the Acoustic Performance of a Switched Reluctance Motor using a combined multi-physics & FEA simulation approach** Ben Meek, Koen De Lange, Koen Vansant, Fabio Santos, Herman Van Der Auwerar, Jan Anthonis, LMS International N.V, Belgium.
16:00	**Calculation of electromagnetic forces in claw-pole alternators for acoustic simulation** Antoine Tan-Kim, VALEO EEM, France.
16:40	**Title to be defined** SYNOPSYS

JMAG Users Conference 2013 will start in Germany.

At the two-day Users Conference in Germany, the first day will be a Technical Day, and the second will see

presentations of users' applications.

At the Technical Day, JMAG Designer Ver.12.1, due for release later this spring, will be debuted early. Also, like at the Users Conference in Japan, time will be set aside for technical discussion, so users will be able to speak freely about the direction of analysis technology and desired functions for JMAG.

For presentations of users' applications on the second day, we are lucky to have presentations by Robert Bosch, Nidec Motors & Actuators, Valeo EEM, Technische Universität Darmstadt, and other technical partners.

Sponsors

Scenes from the 2012 Conference

Editor: Tomomi Igarashi

Event Information
Exhibit Introduction for April-June 2013

JMAG is actively exhibiting at events both in Japan and overseas. Please see how JMAG is performing at the venues. Here we introduce events in April and June 2013 at which we will exhibit.

Virtual Testing and Validation of Controller Software
Conference Outline

Host: dSPACE Inc.

Dates: Tuesday, April 9 - Thursday, April 11, 2013

Locations: April 9：Hotel Arista (Illinois, USA)

            April 11: DoubleTree (Michigan, USA)

URL: http://www.dspace.com/en/inc/home/company/events/dspace_events/seminar_vet_il.cfm

Our North American distributor Powersys Solutions will propose the ECU validation environment for high-precision motor modeling using JMAG-RT and dSPACE ASM. We will deepen our partnerships so that JMAG-RT can be used along with MotorHIL in North America.

CAE Summit
Conference Outline

Host: Otsuka Corporation

Date: Wednesday, April 14, 2013

Venue: Otsuka Corporation Head Office (Tokyo, Japan)

URL: http://event.otsuka-shokai.co.jp/13/0424cae/   (only in Japanese)

JMAG is an electromagnetic field analysis software package for high-speed and high-precision analysis of the complex physical phenomena inside electrical devices. For use by designers, it allows seamless linking functionality with SolidWorks and other CAD software. Because it makes possible geometry revisions in CAD while preserving analysis conditions and material settings, design evaluation can be done in a relatively quick cycle.

Further, JMAG includes tools that can do multifaceted evaluation linked to vibration, thermal, and other results analyzed in other software with pre-loaded workflows, such as JMAG-VTB and Abaqus, so that even engineers who are not well-versed in analysis can carry out advanced analyses.

At this conference, JMAG's functionality and example uses will be introduced, focusing on "JMAG99," Otsuka Corporation's package.

2013SIMULIA Community Conference
Conference Outline

Host: Dassault Systemes SIMULIA

Dates: Wednesday, May 22 – Friday, May 24 2013

Venue: Hilton Vienna Stadtpark (Vienna, Austria)

URL: http://www.3ds.com/company/events/scc-2013/overview/

We will have an exhibit at the SIMULIA Conference, as we did last year.

At our booth, we will present not only electrical design using electric field analysis, but also example applications for users investigating structural design and thermal design at the same time. By combining magnetic field analysis with structural and thermal analysis, product evaluations that used only magnetic field analysis in the past can now be carried out from a wider variety of points of view. Please stop by our booth and check for example applications.

Coil Winding Berlin
- The World's largest International Coil Winding,
Insulation & Electrical Manufacturing Exhibition -
Conference Outline

Host: CWIEME

Dates: Tuesday, June 4 – Thursday, June 6, 2013

Venue: Messe Berlin (Berlin, Germany)

URL: http://www.coilwindingexpo.com/BERLIN/

Engineers gather from around the world, particularly Europe, with booths related to large transformers and wind power generation at Coil Winding, the world's largest exhibition for coils and windings.

This year's JMAG booth will be expanded over last year's, and will feature demonstrations centering on example analyses for motors and transformers. The presentations in our booth are received well every year, so be sure to drop by.

As you can see, we will be quite active in Europe from April to June, especially with the Users Conference in Germany.

You will have a chance to be the first to see JMAG-Designer Ver.12 that is to be released in early summer in 2013 at Users Conference in each country.

In addition, we plan to give exhibits and hold seminars not only in Europe but also countries around the world. By all means, please visit our web site and check the information. We look forward to seeing you at the conference.

（Tomomi Igarashi）
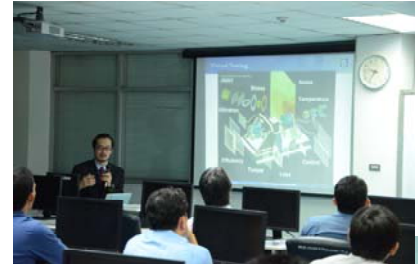
Event Information

Event Report

Attendees report on events held from January to March, 2013. We hope you will attend an event soon.

JMAG Techno Seminar
Conference Outline

Host: JSOL Corporation, JSIM Ltd.

Date: Tuesday, February 12, 2013

Venue: King Mongkut Institute of Technology Ladkrabang (Bangkok, Thailand)

In recent years, construction of distribution networks and technical training for operations and sales in China, South Korea, and Southeast Asian countries has progressed in order to keep up with the movement of business by customers moving their product development and design overseas. Thailand has particularly seen advances in Japanese manufacturing over a long period of time, and its infrastructure has formed faster than other developing countries as most current customers have expanded there. At first, the focus was on physical manufacturing, but design, research, and development have slowly been taking some of the share of local manufacturing.

With this background, we held a JMAG Techno Seminar for our Thai customers. This was the second seminar introducing JMAG in Thailand.

For advanced product development using simulation, not only the introduction of software, but also knowledge of materials and electromagnetic field phenomena as well as a lot of peripheral knowledge is necessary. With the cooperation of JSIM Ltd., who have experience with most CAE software, JSOL was able to provide technical support for customers through local engineers.

In the morning, we explained basic ways of thinking about electromagnetic fields in addition to an introduction to JMAG, and in the afternoon attendees were able to practice motor and transformer analysis using actual terminals. It was a quite lengthy and hard seminar, but the attendees were very enthusiastic and the question-and-answer continued even after the official end of the seminar. JSOL will endeavor to create a structure to provide the apex of CAE solutions and carry one part of our customers' global strategy.

(Takahiko Miyachi)

Multiphysics Simulations Using Abaqus and JMAG for Electromagnetic Equipment Design
Conference Outline

Host: Powersys Solutions、Dassault Systemes SIMULIA

Date: Wednesday, March 6, 2013

Venue: Dearborn (Michigan, USA)

URL: http://www.powersys-solutions.com/Seminar_Multiphysics_Simulations.php

A seminar on linked analysis with JMAG and SIMULIA Corporation's Abaqus structural and thermal analysis software was held at SIMULIA's Dearborn offices. There were about 20 structural design engineers and other attendees at the seminar, mainly related to Detroit's automobile industry.

At the seminar, we gave a presentation including examples of phenomena that can be analyzed by taking advantage of JMAG's electromagnetic field analysis functions along with Abaqus' thermal and structural analysis functions, such as high-frequency induction heating of structural parts, effects of heat and stress on motor characteristics, effects of heat stress when current flows in a busbar, etc. Even after the seminar, we received many questions from attendees about individual issues, which showed us the amount of interest in this technical field.

(Tetsuo Ogawa)

Modern Simulation for Electric Motors Seminar
Conference Outline

Host: LMS International, Powersys Solutions

Date: Tuesday, March 12, 2013

Venue: LMS North America Office (Michigan, USA)

The LMS Seminar was a 1 day event held at LMS's Troy, Michigan offices. There were approximately 26 attendees from a variety of companies. The seminar discussed how to model electromagnetic forces and incorporate those results into a noise and vibration simulation. The first half of the day focused on modeling electric motors in JMAG, specifically an IPM machine and a SR machine. The second half of the day discussed how to transfer the forces to LMS's Virtual.Lab for further analysis, including correlating the results with actual measurements. There attendees asked many good questions about this process and had very positive feedback. They liked the fact that linking JMAG and Virtual.Lab is becoming more seamless and they were interested in identifying applications that could benefit from this capability.

(Dave Farnia)

GPU Technology Conference (GTC) 2013
Conference Outline

Host: NVIDIA Corporation

Date: Wednesday, March 20, 2013

Venue: San Jose McEnery Convention Center (California, USA)

URL: http://www.gputechconf.com/page/home.html

The NVIDIA GPU Technology conference was held in San Jose, California and had attendees from every facet of industry. The purpose of the event was to present the advances in GPU (Graphic Processing Unit) technology. Whereas GPUs were only used to display graphics, they are now competing with CPUs in processing functionality. NVIDIA is a leader in moving this technology forward and the progress they have made is startling. The atmosphere was boisterous due to all the breakthroughs that NVIDIA announced. There were, of course, demonstrations of visualization improvement including 3D displays and more elaborate rendering. But there were also examples of GPUs being used to in server type applications or reducing computation time. JSOL's paper discussed how customers are using GPUs to realize substantial analysis speed improvements. And from the conference, it seems that the rapid performance improvements in GPUs will not slow down any time soon.

（Dave Farnia）

JMAG Users Conference 2012
Presentation-day handout materials now available "For Users Only"

Presented papers and workshop materials from the JMAG Users Conference 2012 are now available on the our users-only website. Please feel free to download them.

http://www.jmag-international.com/support/en/documentation/seminar_uw2012.html

*A user ID and password are needed to access the site. If you do not know yours, please contact the person responsible for the license at your company.

This issue's Event Report focuses on exhibitions held in the United States. JMAG will continue to not only provide technical support, but also provide better products that can carry a part of our customers' global strategy in the future.

Editor: Tomomi Igarashi

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Simulation Technology for Electromechanical Design