Simulation Technology for Electromechanical Design

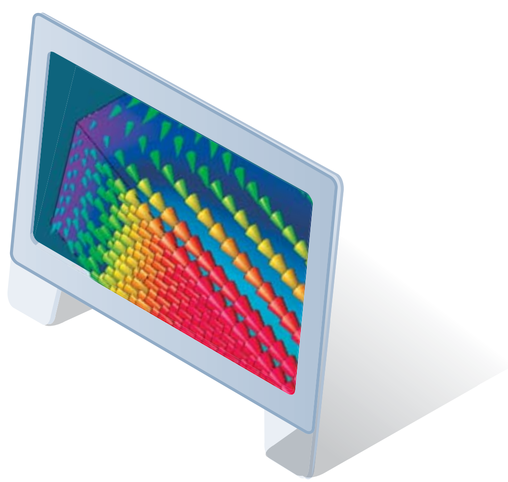
JMAG

JMAG News Letter

2011 Summer

It is now simple to be precise

JMAG is a comprehensive software suite for
electromechanical equipment design and development.
Powerful simulation and analysis technologies provide a new standard in
performance and quality for product design.
Capture complex phenomena and gain valuable insights.



Simulation Technology for Electromechanical Design
http://www.jmag-international.com

JMAG

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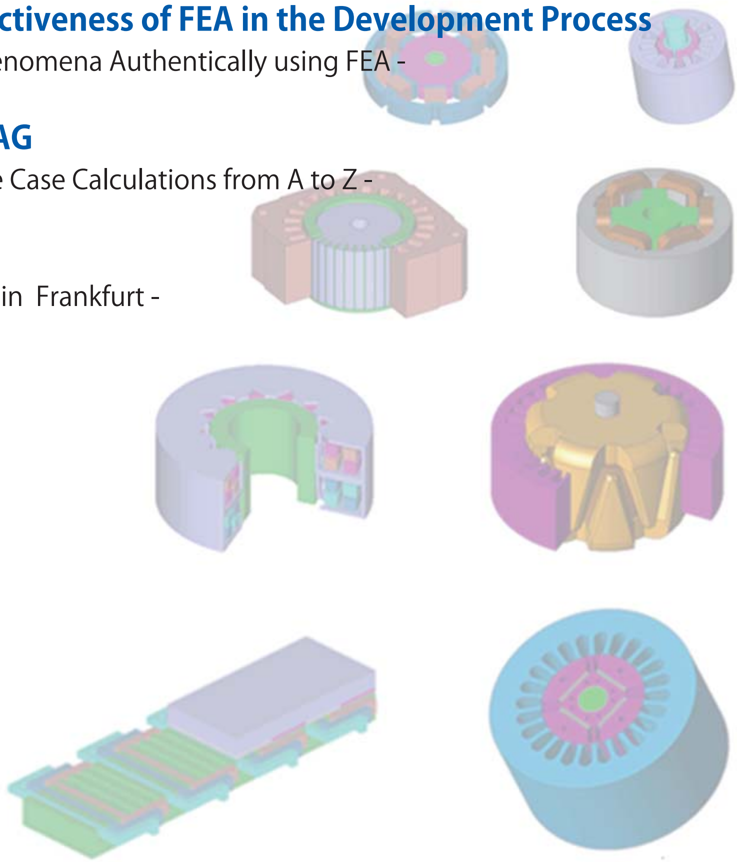

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JMAG News Letter Summer Edition

The summer edition of the JMAG News Letter introduces the power of JMAG-Designer 10.5 released in July, 2011.

The latest version can be used with confidence to perform even more efficient analyses because of the enhanced usability and performance.
In this special issue of the product report, the new features are introduced along side primary examples in addition to describing the aim of development for JMAG-Designer version 10.5. Many of the features that have been required by our users have been implemented in this version.

JMAG A to Z shows innovate ways of using JMAG.
This report introduces features that may be unknown to even very versatile JMAG users as well as shows unique ways to perform operations more efficiently as JMAG is continually being innovated. We hope that ti s report will bring even more efficiency to your design process.

The event report introduces the large scale JMAG Users Conference in Germany held by JMAG in Europe in addition to our other events in America and China.
JMAG will be holding more events around the world in the future. Please see the event schedule to find events in your area.

The JMAG News Letter is valuable for everyone from those currently using JMAG or those just starting to use JMAG to anyone that is not presently using JMAG
Please don't hesitate to introduce our newsletter to those just starting to use JMAG around you.

This issue is packed with even more information than ever before. We hope you enjoy it.

Electromagnetic Engineering Department
Engineering Technology Division
JSOL Corporation

Product Report

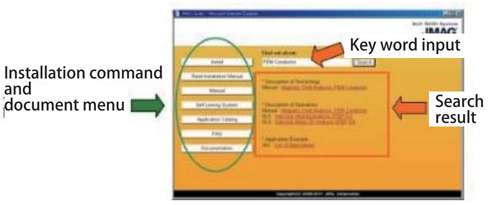
JMAG-Designer version 10.5 was released

The development of this version of JMAG-Designer implements various features aiming to improve performance as an experiment and evaluation device by advancing the analysis capabilities while reducing the work required by the user for a more efficient analysis process and ease of use.

Features that were only available in JMAG-Studio previously have been built into JMAG-Designer while also improving their usability. These features allow each analysis to be performed more efficiently while reassuring anyone using JMAG-Studio that JMAG-Designer not only satisfies their needs, but exceeds their expectations. Don't hesitate to try and evaluate JMAG-Designer yourself.

Powerful Guide Features

In addition to the Self Learning System (SLS) currently available to productively learn JMAG, a Self Guiding System (SGS) has been added to support users as they encounter problems, such as JMAG terminology they don't understand or where to find documentation when running their own analyses. The documentation that is needed can be found simply by entering a keyword.



Self Guiding System

Highly Controllable Mesh Features

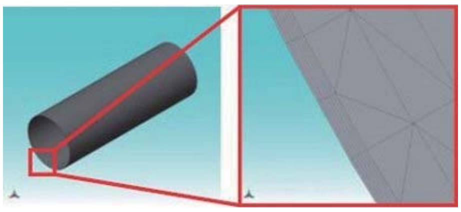
Having technology that can generate mesh in the desired areas is vital when using the finite element method. Technology that can generate this mesh appropriately is required to have an adequate balance between the analysis accuracy and analysis time.

JMAG offers features that can generate mesh without requiring additional effort by the user to simulate the physical phenomena which is unique to electromagnetic field analyses, such as mesh modeling the skin effect and rotation periodic mesh. The ability to simulate thin plate models more accurately has been enhanced in this version when generating mesh.

Generate Thin Plate Mesh

Generating mesh for an extremely thin plate model in the analysis space, such as a shield or chassis panel, is difficult using conventional mesh generation methods. However, the thin plate mesh feature can generate a sufficiently large mesh in the plane direction based on the layer of mesh that is generated in the thickness direction. The analysis time is reduced and the accuracy improved for problems related to the scale of a model, such as analyzing shield rooms and the eddy currents that are produced in thin plates.

This feature can only be used for the magnetic field analysis because conditions cannot be set to thin plate mesh at this time.

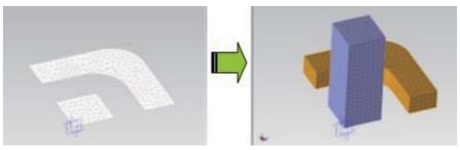


Generate Thin Plate Mesh

Manual Mesh Editor

A manual mesh editor has been added to JMAG-Designer based on the requests of our users limited by only being able to generate mesh automatically. Manually generating mesh allows the experience gained generating mesh in JMAG-Studio to be applied to analyses run in JMAG-Designer.

Just like JMAG-Studio, mesh can be generated using triangle/square elements for 2D models and a 3D model can be created by dragging the 2D mesh model. These features have been enhanced even further in JMAG-Designer to make creating geometry easier using clear interface.



Manual Mesh Editor

Reinforced Material Features

The calculation solver and modeling, such as the modeling of materials, is vital to run highly accurate analyses. JMAG provides various properties for magnetic materials as a database with the help of the material manufacturers. Reinforcing the material features is a primary point in the development of JMAG, especially for this version.

Including BH curves of Structural Materials from Vacuumschmelze

Magnetic properties for general structural materials of steel that have been so highly requested, such as S45C and SPCC, have been added to the database. These magnetic properties were added using measurements from research institutes which contribute to improving the analysis accuracy.

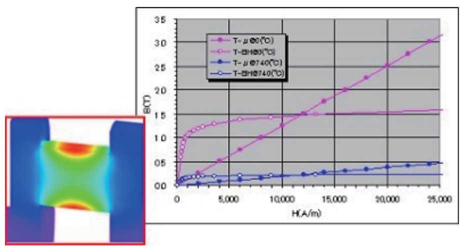
In addition, magnetic properties from Vacuumschmelze (VAC), a dominant magnetic material manufacturer in Europe, have been added to the material database. Properties including silicon steel and permalloy type soft magnetic materials are now there for you to use as necessary.

Temperature Dependent Magnetic Properties

Temperature dependent magnetic materials have to be used to improve the accuracy when running coupled thermal and magnetic field analyses that have large temperature variations. The temperature dependent magnetic materials that have been supported by user subroutines have been standardized.

These properties allow phenomena, especially in the magnetic saturation region, to be simulated more accurately than models using the conventional temperature dependent permeability. The accuracy has been vastly enhanced for analyses that have temperature variations over a wide-range caused by large currents, such as high-frequency induction heating.

However, the user needs to define these properties because the temperature dependent material properties are not part of the material database.



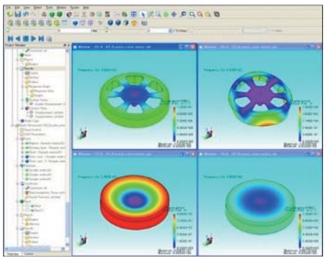
Temperature Dependent Magnetic Properties

Versatile Display Features

JMAG also focuses on developing features capable of displaying the analysis results as clearly as possible, which are indispensable to simulation software as a measuring instrument or experimental device.

Multiview Feature

The multiview feature is a feature to display multiple windows in the graphics screen. For example, the problem causing iron loss can be grasped quickly in addition to the areas that the iron loss is produced by displaying and comparing the magnetic flux density distribution and iron loss distribution. The structure can also be evaluated easily to limit vibrations resulting from the relationship of the magnetic flux density distribution, electromagnetic force, and deformation comparing the results obtained in a magnetic field analysis and structural analysis.



Multiview Feature

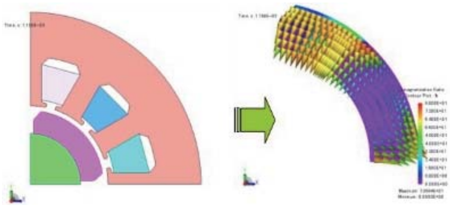
View Control

The viewpoint used to display a model can now be defined more easily using numerical settings. Models can now be displayed from a more specific viewpoint. The ease of creating reports can be further increased by combining this feature with the viewpoint list. This feature combined with the multiview feature provides an even clearer evaluation of the analysis results.

View Control

Displaying the Demagnetization Ratio of Magnets

The demagnetization ratio of magnets can now be displayed. The behavior of the magnetic flux density variations can be pursued by setting the base condition of the magnetic flux density for magnets. An even more comprehensive analysis of magnets is made possible using a similar feature, the permanence coefficient distribution, with this feature.



Displaying the Demagnetization Ratio of Magnets

User Components

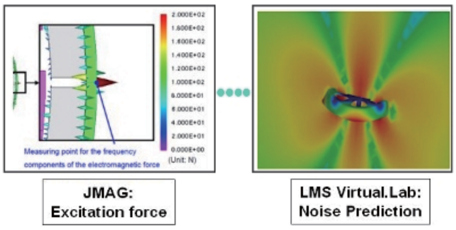
User components are a feature that runs user-defined calculations in the post-processing for physical quantities obtained in a JMAG analysis. The analysis results can be evaluated based on the criteria the users would like to focus, such as the physical quantities after running four arithmetic operations that have been defined, or displaying the maximum/minimum of all the steps for the hysteresis using a contour plot. User components are available in JMAG-Studio, but they have been revolutionized for better usability for implementation into JMAG-Designer.

Reinforced Coupled Analysis Features

Improving the overall performance of JMAG independently is very important, but the analysis capabilities can be further extended by having greater synergy when linking to advanced third-party software for coupled analysis. JMAG strives to strengthen its linking capabilities with third-party solutions based on the concept of an open interface. This version of JMAG has the capability to link to LMS Virtual Lab. Other links, such as expanding the conventional link to SPEED to SPEED-IM, have also been implemented.

Linking to LMS Virtual Lab

The coupled analysis feature with LMS Virtual Lab brings new added value to JMAG. The highly accurate electromagnetic force results obtained in JMAG can be utilized as excitation force in the powerful structural or noise analyses in LMS Virtual Lab. The link to LMS Virtual Lab is invaluable in investigating ways to reduce the vibration and noise of motors.



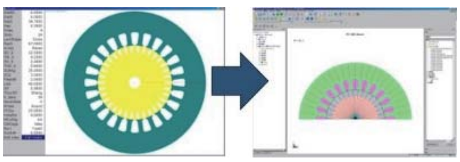
Linking to LMS Virtual Lab

SPEED Link

SPEED-IM Link/SPEED-BLDC Link

The analysis models created in SPEED, a universal motor design tool developed by the University of Glasgow can now be imported into JMAG. The concept design can be undertaken quickly using SPEED through he benefits of the magnetic circuit method, and then a more comprehensive evaluation can be performed seamlessly using the highly accurate analysis capabilities of FEM.

The geometrical and settings information is imported into JMAG-Designer by simply specifying the settings indicated in the dialog box displayed by selecting GoFer in the SPEED tools menu after running the SPEED analysis. A subsequent analysis can be run by specifying additional settings, such as the conditions necessary for FEM, in JMAG-Designer. The motors that are currently supported are the BLDC (brushless motor) and IM (induction motor).



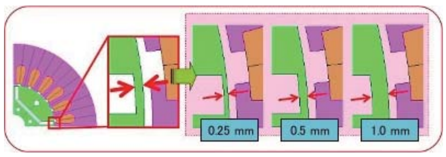
SPEED Link

Parametric Features

The actual design process demands designers are able to run various evaluations and make decisions extremely quickly. An analysis with multiple cases can be run efficiently. A primary example is a sensitivity analysis for design parameters. JMAG-Designer has strengthened the parametric features with a case control and graph manager previously, and this version is no different reinforcing them with the following features.

Parametric Functions

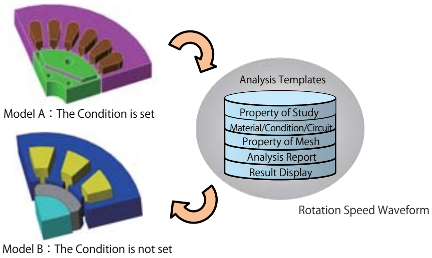
The parametric function is a feature to increase the workability of the parametric analysis that is beneficial to JMAG-Designer. Functions can now be defined in addition to the numerical and discrete values that have been available in the case control for the parametric analysis by defining a constant and an equation for the parametric function. The frequency (Hz) of the U, V, and W phases for the power supply can be synchronized by simply changing the common frequency (Hz), A, by setting the common frequency (Hz) to A = 120, and then specifying $U=2\pi A+0$, $V=2\pi A+120$, and $W=2\pi A+240$ if applying a 3-phase power supply using a sinusoidal function.



Parametric Functions

Reinforced Analysis Templates

The analysis templates used to share information, such as the condition settings, material properties, and post-processing as a template have been reinforced. The succession of settings such as conditions were originally defined by the names of parts in JMAG-Designer, but now the succession of condition settings to faces and edges can be maintained by configuring data called a set. As a result, the advantage of analysis templates has been greatly improved.



Reinforced Analysis Templates

New JMAG-RT Features

The features for JMAG-RT, a solution for model based design, have been further enhanced based on the requests from our users.

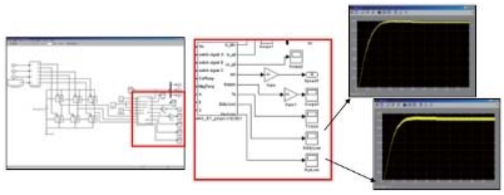
- Account for iron loss in PM motor models
- Utilize the new SR motor model
- Utilize the new induction motor model
- Create motor efficiency maps using JMAG-RT VIEWER

These enhancements are currently only supported in Simulink, but support for PSIM is coming soon.

Account for Iron Loss in PM motor Models

Drive methods, such as flux weakening control are used and the evaluations of the control are becoming highly developed because PM motors demand high efficiency over a wide drive region. The iron loss can now be taken into account for PM motor models to meet the increasing needs for more highly developed investigations. An interface has also been added to specify settings for the coil and magnet temperature as well as increasing the capabilities to simulate models that can reflect the output.

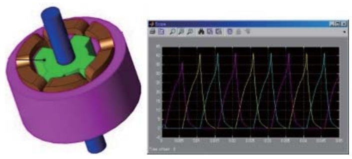
The torque and the inductance were originally extracted when creating JMAG-RT models, but now a process has been added to calculate the iron loss using the analysis results. The iron loss for the behavior model is not simply expressed by the series/parallel resistance, but independent technology for high fidelity JMAG-RT models offers both higher speed and higher accuracy.



PM motor Model

Utilizing the New SR Motor Model

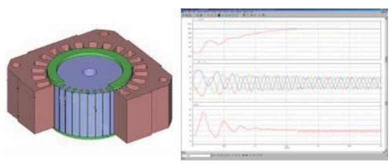
SR motors are gaining attention as motors that do not use permanent magnets. This version of JMAG adds an SR motor model to the JMAG-RT system. SR motors have large spatial inductance variations and they are strongly affected by nonlinear materials. These motors are extremely difficult for the drive control because the torque fluctuations are extremely severe. The highly accurate SR motor model is very beneficial for investigating ways to improve efficiency and reduce the torque variations using the control of the SR motor.



SR Motor Model

Utilizing the New Induction Motor Model

Induction motors are a mainstream motor still widely used in the market today because they are easy to control and they have a robust structure. The demand for higher performance induction motors is increasing resulting in a greater need for magnetic field analysis related to these motors. An induction motor model has been added to JMAG-RT to address this demand.



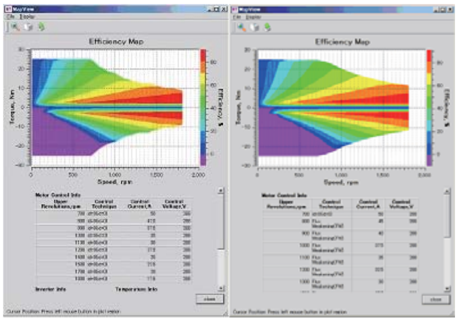
Induction Motor Model

Motor Efficiency Maps

Efficiency maps are advantageous as a measure to evaluate the total performance of motors. However, the procedure to create efficiency maps is very laborious whether using actual measurements or analysis. The JMAG-RT VIEWER has been developed to generate efficiency maps and speed-torque curves using the JMAG-RT model as a fundamental part of model-based design solutions.

An efficiency map can be generated quickly by specifying the drive condition and control information for the JMAG-RT motor model (*.rat) using the JMAG-RT VIEWER. The overall characteristics of a motor lay are very accessible because the Ld/All and loss can also be displayed as a map.

The JMAG-RT VIEWER can be used to confirm the aspects of the motor model created by the user as well as be used by the control designers and motor users to confirm the motor data that they are given. The JMAG-RT VIEWER is also free software with license authentication.



Motor Efficiency Maps

New Features Added to JMAG-RT Library Manager

The features of the JMAG-RT Library Manager have been enhanced.The RTT files created in versions earlier than 10.5 can be converted to the 10.5 format.This allows older RTT files to be evaluated using the JMAG-RT VIEWER.The value of distributing JMAG-RT models has further benefits by including more information in the RTT file by including more information in the header and comments.

A feature to create RTT files from user data has also been added.A behavior model equivalent to an Ld/Lq model can be created by specifying the current dependency of the inductance.

Reinforced JMAG-Bus Features

JMAG-Bus is a framework customizing the analysis process which is capable of being shared between many people that can be used without installing or learning any of the operational procedures used in JMAG This version of JMAG-Bus has improved the efficiency of the analysis process by adding new features and enhancing the performance of JMAG-Bus.

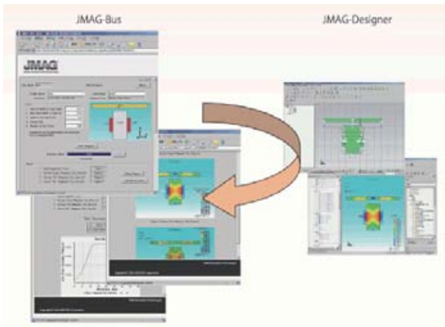
Enhanced JMAG-Bus Features

The three features below have been added to enhance the performance of JMAG-Bus. These innovations have made the analysis process even easier than before.

- User management features: Privileges can now be specified for each user in JMAG-Bus.

- Folder to save analysis data: The folder to save analysis results can now be sequentially changed.

- Installer support: A JMAG engineer previously needed to perform the installation of JMAG-Bus on site to configure the system, but now an installer has been developed for the setup process.

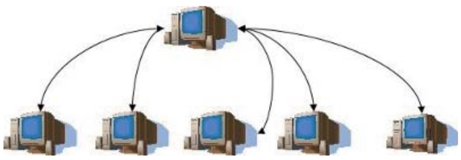


Enhanced JMAG-Bus Features

Other

Snapshot Analysis

The snapshot analysis is a feature to obtain solutions rapidly by separating each step of an analysis with multiple steps to multiple machines over a network. The snapshot analysis is beneficial for models that are not affected by transient aspects requiring information to be passed from step to step, such as cogging torque analyses.

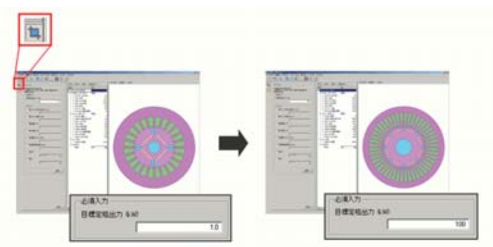


Snapshot Analysis

Sizing Feature for JMAG-Express Geometry

The popular motor design tool JMAG-Express now has a geometrical sizing feature. Conventionally users needed to specify settings such as the dimensions and drive conditions when using the basic templates, but now the sizing feature recommends geometry and drive conditions by simply specifying the minimum desired output of the motor. Of coarse more specific geometry and drive conditions can be obtained by increasing the amount of information that is specified.

JMAG-Express can now be used as a building block to examine the geometry and drive conditions even for users that are not versed in motor design.



Sizing Feature for JMAG-Express Geometry

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Model-based Development

Issue 2 Upgraded Functions for JMAG-RT

The fundamental efforts of JMAG for “model-based development (MBD)," which is starting to be applied to the development process as introduced previously, are outlined in this document. The new features of JMAG-Designer version 10.5, which was released on July 13th, for MBD are also introduced.

Aim of the Latest Version

JMAG is being developed recognizing the importance of MBD. The principle of MBD is to provide a highly accurate model as close to the real prototype as possible that can be used easily. Currently, JMAG is addressing MBD from two fronts.2

1. MBD using JMAG-RT
2. MBD to link thermal, structural, and magnetic design

In thisNewsletter,1.,JMAG-RT, has been introducing the new features recognizing MBD which is realized by multiple plant models.

The accuracy and a high processing speed while being easy to used is demanded of models in system development including multiple ECUs because the logic consistency and synchronized speed between each ECU is evaluated. The solution that is recognized for this type of MBD is JMAG-RT. Whether the system can operate normally while processing abnormalities is evaluated assuming problems, such as sensor trouble or errors in operation occur. Whether or not the relationship between the parts as a system and whether or not the behavior of the system that is intended is achieved is also confirmed.

Accounting for Iron Loss in Motor Models

As described previously, the accuracy of the model is vital to MBD. The demands of PM motors are increasing for both higher efficiency and output while also requiring further miniaturization. The direction of development focuses on gaining output through higher rotation rather than increasing the torque using a larger heavy motor to satisfy these demands. This causes the ratio of the iron loss in the total loss to increase dramatically. The appropriate control for the drive of the motor needs to be used to realize higher efficiency considering this loss. The motor control becomes difficult when determining where to limit the iron loss in a region that is not normally used for a motor because the drive mode has a motor that is pulled along by the engine during operation(high rotation speed at a low load), such as hybrid vehicles, and the iron loss becomes the largest ratio of loss.

The PM motor model for JMAG-RT has realized a highly accurate model by accounting for nonlinear materials and detailed geometry, but the accuracy of the model is further enhanced because the iron loss characteristics can now be embedded. This information can contribute to the efficiency of the entire system because determining whether the loss is allocated to the motor or the inverter can be judged accurately by an even more precise motor model.

Furthermore, a simulation with more accuracy than linear models can be run because the iron loss characteristics are taken into account even for the IM motor model that has just been added.

An input terminal to account for the magnet flux and temperature dependency of the copper loss in the coil has been added to the behavior model. The temperature behavior can also be evaluated as a system which changes the motor characteristics by specifying the operational temperature in Simulink.

We talked with the engineer that developed the iron loss feature for the PM motor model in JMAG-RT, Katsuyuki Narita.

Q1. Why did you decide to add the iron loss feature to the PM motor model?

A1.Many customers where having problems where the torque and voltage did not match in simulations using JMAG-RT models, especially in the high speed region where the effects of the iron loss is large. In addition, there was a demand to be able to obtain the iron loss information to measure the temperature of the motor.

Q2. Why wasn't the iron loss previously available in the JMAG-RT model? Was it technically difficult?

A2. Modeling was conventionally undertaken considering parallel equality iron loss resistance, but the behavior of the loss when changing the current and rotation speed in the iron loss resistance had problems matching the measured results of prototypes and the transient analysis results of JMAG. For example, the iron loss is constant regardless of the rotation speed for a constant voltage in the conventional parallel equality iron loss resistance for a motor driven by an open loop voltage input. This is unnatural when you think of the iron loss for a permanent magnet motor.

We had been unable to find a way around this problem until we developed a modeling method that could fully use the iron loss information calculated in JMAG that we released.

Q3. What was the benefit of examining a modeling method concurrently while experimenting on a prototype?

A3. A good example is measuring the difference of iron loss by creating motors using different grades of electromagnetic steel sheet. The difference in the iron loss caused by the drive control method was also evaluated. Extremely valuable information was gained for the modeling of the iron loss because these results clarified the various behaviors of the iron loss. Of course, being able to verify the modeling method we developed against the actual measurements was also very important.

Q4. What were some of the aspects that made this project difficult to bring together and release as a product?

A4. I am sure this is obvious, but I had a lot of trouble getting the modeling of the iron loss usually obtained in an analysis using JMAG and the iron loss exported from the JMAG-RT model to match. I worked as hard as I could to get it right because the demand of our JMAG users was so high.

Q5. What did you think after you actually started using the model after succeeding in making it a product?

A5. I felt like I had resolved the problem of the torque being overestimated in the high speed region and not matching in the low speed region in control simulations for MBD. I hope that people will use it because it is also effective in measuring the temperature of motors.

Q6. What are some of the other enhancements you would like to make in the future?

A6. I am confident that the model accuracy has vastly improved because the core iron loss can be taken into account in this version we released, but the eddy currents that occur in the iron loss and magnets due to PWM modulation and spatial harmonics.

Adding an Induction Motor and SR Motor Model

Permanent magnet motors are not the only development challenges. There are still a larg number of induction motors being used throughout the world. Induction motors provide a wide-range of advantages such as a robust structure that doesn't need a special control to run as well as not requiring any magnets. Of course, better efficiency is expected from induction machines which requires the appropriate control. The cost for improving the performance of the control microcomputers of motors for powerelectroncis is decreasing in addition to the cost to improve VVVF and the vector control. These demands are why an induction motor has been added to JMAG-RT. The actual material properties and the magnetic circuit geometry are faithfully reproduced because the behavior model is generated from a JMAG magnetic field analysis just as the PM motor and stepping motor models.

A model of an SR motor which has gained attention as a motor without magnets has also been added. The origin of SRM itself is old, but the drive control is difficult because SRM have strong nonlinear characteristics with large inductance variations and they never became used widely because torque fluctuations are large.

The characteristics of the SRM have not changed, but these flaws can be overcome today by using more advanced magnetic design technology and drive control technology through electromagnetic field analysis. Motor engineers are gaining more interest in SRM because higher performance can be achieved. JMAG has added an SRM behavior model in the latest release. The SRM motor model contributes to comprehensively examining the control because the extreme current variations and torque can be reproduced authentically and the nonlinear characteristics of the inductance is modeled highly accurately.

These innovations will continue to be implemented into JMAG-RT improving the accuracy of the motor model while expanding the variations of models to satisfy the users needs.

Creating JMAG-RT Motor Models from JMAG-Express and Table Data

Inverter designers are not interested in the arrangement of the slot geometry and magnets, but see motors as inductance, resistance, and a power circuit. However, the ability to determine the motor design parameters or have a novice user create data to generate JMAG-RT motor models is thought of as being difficult. JMAG-Express is the tool that resolves this problem. A user inexperienced in motor design can create a model simply and then use the results that are obtained to generate a JMAG-RT motor model because the performance can be confirmed by creating that model easily in JMAG-Express. This means that a JMAG-RT motor model can be generated with ease even by an inverter designer.

A feature to create a JMAG-RT motor model from measured data such as inductance and torque has been added to allow users to create models from data tables. A motor model that is difficult to achieve by changing geometry, such as pushing the boundaries of the motor parameters, can be incorporated into a motor model to evaluate the control design.

These features allow everyone, not just motor designers, to be able to generate JMAG-RT motor models simply.

Using JMAG-RT Viewer to Share the Value of Motor Models

The above discusses the value of having the JMAG-RT motor models themselves, but some users have pointed out that they are difficult to use. Conventionally, a JMAG-RT motor model needed to be placed in a control simulator to see the actual JMAG-RT motor model, because JMAG-RT was originally a solution to increase the speed of control simulations.

A JMAG-RT Viewer capable of displaying the information in the JMAG-RT motor model (rtt file)has been developed to address this problem. The JMAG-RT Viewer is very useful for control designers that would like to review the motor characteristics, but it also allows motor designers to confirm their own motor characteristics because the JMAG-RT Viewer can create efficiency maps to examine the overall performance (T-N-η characteristics)as well as made the inductance(I-β-Ld/Lq)to display as the motor characteristics.

Conclusion

The above has focused on describing JMAG-RT based on the features that are available. These features further expand the range that JMAG can be used for MBD and we are confident it will contribute to system development. The next issue will introduce MBD using coupled analysis features.

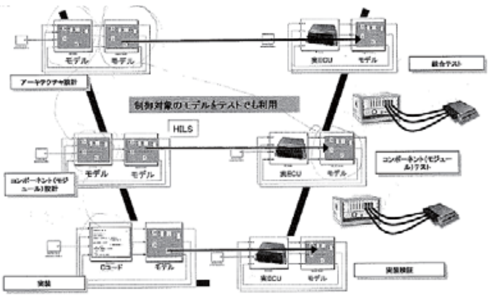
Forefront of Model-based Design

dSPACE Interview

Currently, model-based development (hereinafter MBD) for the field of power electronics including motors has not gained full momentum, but a large number of the top ECUs to control motors have implemented MBD. Everyone presently using JMAG will be unable to avoid implementing an MBD environment in the future. We talked with Takashi Miyano, Director of the Engineering Department at dSPACE Japan who provides the development tools to automotive ECU development, which is breaking new ground in MBD, to find out more about what is currently happening at the forefront of MBD.

Trends of MBD

Saying that automobiles have become a bulk of computers is not going too far as shown by the halted production of vehicles due to the micro-computer manufacturers for automobiles that feel victim to the earthquake in northern Japan. Vehicles have to connect the ECUs utilized in engine units including the engine, power steering, and breaks as well as the ECUs built into amenity units like air conditioning and navigation systems. A massive overall program is required to combine each of these ECUs that have their own control programs. The overall evaluation is also enormous because each independent unit needs to be confirmed in addition to examining everything at a system level.



V-cycle for MBD

Mr. Takashi Miyano, Director of the Engineering Department at dSPACE Japan

Forefront of MBD

dSPACE considers the same MBD to have significant differences for model-based design and model-based development. "Model-based design" is development using simulations, which is where the process often stops. On the other hand, "model-based development" greatly differs by using a model that is created for the next process. The plant model and ECU control model generated in source code is maintained and utilized until the final production. In other words, model-based development is an image of development encompassing the entire development process. dSPACE develops products that can be used for model-based development.

MBD is becoming more prominent in the development of aircraft and weapons that are difficult to examine in real prototypes, but, presently, the automotive industry is at the forefront. Europe could be considered a step ahead of Japan in implementing MBD.

The MBD environments provided by dSPACE are MicroAutobox, a model to construct ECU and control programs that are built-in and the RaridProunit to construct the plant (control targets such as motors, actuators, and sensors). These interfaces are arranged so that a hardware-in-the-loop simulation can be configured. The fundamental point is to automatically generate the C code for the ECU from the control model of the ECU created in upper processes in real time simulations using MaicroAutoBox and PapidPro. MaicroAutobox has a calculation performance that can reproduce the ECU, but a control period of100 MHz/10 nsec can be achieved by using an FPGA board, which is required for extremely high performance calculations of modeling related to power electronics and image recognition.

Universal controller MicroAutobox

Universal plant unit RapidPro

Plant models, another vital key equivalent to ECUs in MDB, are refined by each user. The experience of the user is shown by what physical aspects should be embedded in the model. Evaluating the validity of a model is determined by rotating it through the V-cycle. Discrepancies in the model are found as a model moves to proceeding processes if the accuracy of the model is not sufficient because the system does not operate correctly, etc. If the cause of the discrepancies is the model, the problem is fixed and the V-cycle is repeated again.

1/3 of the source code for ECUs is for diagnostics. Whether or not the control system is configured so that it doesn't enter a dangerous mode as an entire system has to be confirmed even if a disturbance occurs, such as a broken wire or noise between the sensor and ECU or damage including plant breaches. These examinations also have to be performed of course in real time.

Mr. Miyano's lecture about the extreme advantages of using MBD for ECUs and program development has been very informative. I asked Mr. Miyano to elaborate further for me as a designer close to plant design.

(JMAG)

This has been very informative about the amazing advantages of using MBD for ECUs and program development, but implementing MBD doesn't seem to affect the JMAG users who are closer to plant design. What are the benefits of implementing the MBD environment for plant designers?

(Mr. Miyano from d SPACE)

Demands for plants using MBD allow more specificity and detail. For example, there are requests like the torque variations of the motor need to be kept under X.XN-m. On one hand, the requirements may become stricter, but the sensitivity and the priority during optimization of the entire system becomes clear. There are also some aspects that may become easier for plant designers because the margin each designer is responsible for becomes clear.

This final answer has cleared up any misunderstands I had.
MBD is something that engineers are hoping for if it has fair tradeoffs between the plant and control designers, and not whichever side has the loudest voice. This interview has really showed that the efficiency of development using MBD not only reduces the time of development, but also effectively shares information and the decisions that have been made.

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Explaining FEA Effectiveness of FEA in the Development Process

Issue 2 Reproducing Phenomena Authentically using FEA

Electromagnetic field finite element analysis (FEA) has been rapidly expanding as a tool used in the development process over the last 15 years.

The application of FEA varies based on the needs of each development process, but why has FEA expanded so rapidly as a tool for development? In addition, what are the advantages of using FEA in the development process?

Impact of FEA on the Design Process will introduce how FEA has effected the development process from multiple perspectives over the next year.

1 . Preface

In the last issue, the prevalence and background for finite element analysis (FEA) showing the amazing advances in recent years was introduced. The ability to authentically reproduce physical phenomena using analysis calculations is one of the reasons FEA has so widely penetrated the design process.

This issue looks at the features of FEA that are capable of achieving this high reproducibility.

2 . Achieving a High Reproducibility from the Perspective of the Resolution

FEA expresses models as mesh, which is a collection of elements dividing the analysis target. In addition, FEA can express the data required for analyses including point sequences for input waveforms varying by time and material properties that have nonlinear characteristics. FEA is able to run analysis with a high resolution by increasing the detail of the mesh and input waveforms allowing the physical phenomena to be reproduced highly authentically.

This section delves into the reasons FEA is capable of attaining this high resolution from the following 4 aspects of the analysis:

a. Creating the model geometry
b. Defining the governing equations
c. Specifying the material properties
d. Specifying the drive conditions

2-a. Creating the Model Geometry

The geometry of the electromechanical machines is wrapped in innovations to obtain the desired output while considering the various restrictions. For example, the gap structure between the rotor and stator have tremendous effects on the output characteristics of motors and this is one aspect of the design requiring a vast amount of experience. The characteristics are also largely affected by small geometrical differences in the primary magnetic pathways of motors using magnetic saliency, such as reluctance motors. The cogging torque of a motor that has pits in the tooth ends is largely reduced when compared to geometry without pits, as indicated by Fig.1.

The magnetic resistance for each part making up the magnetic circuit is obtained using integral calculations in the magnetic circuit method often used in simplified design, but the number of calculations greatly increases for the parts required to gain higher accuracy if the geometry is complicated. Therefore, the intuition and experience of the thermal designer is indispensable when selecting the parts required for the preliminary calculation. There are also restrictions to the geometry that can be handled because there is geometry that makes calculating the magnetic resistance challenging in elementary integral calculations for complex geometry.

On the other hand, FEA can use the geometrical data from the CAD diagram to create models.
FEA defines the geometry as mesh that is a collection of elements divided into the finite element space for the analysis target (see Fig.2). The mesh model of the analysis target does not rely on selecting the geometry of the analysis target or the skill of the engineer because mesh can be generated using automatic mesh generation features if the geometrical data is available.

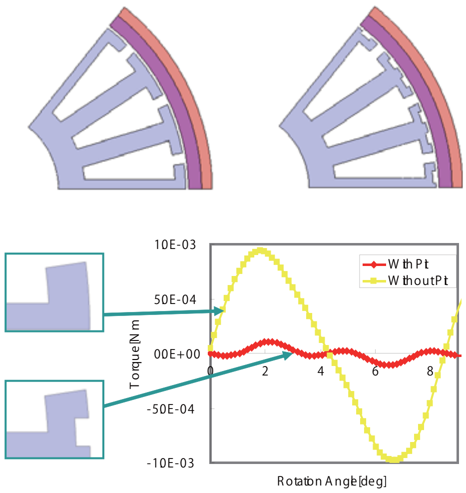

Fig.1. Comparing cogging torque for geometry with and without pits on the teeth ends

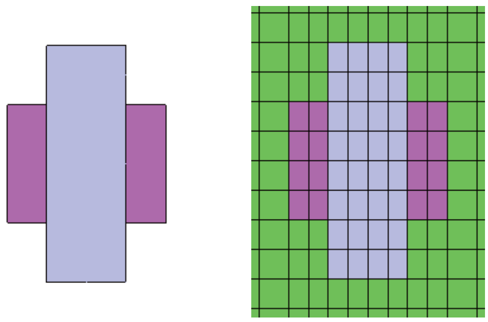

Fig.2 Geometry of an electromagnet model and mesh after discretization

2-b. Defining the Governing Equations

Maxwell's equations are the fundamental equations governing electromagnetic phenomena. These equations need to be treated accurately without approximation to achieve an analysis that can reproduce results obtained from actual measurements. Maxwell's equations are expressed by partial differential equations including time and space derivatives that are generally difficult to manually analyze correctly if the geometry is not simple with good symmetry. Analysis using numerical calculations is also required for an analysis that can account for the nonlinear magnetization properties and conductors.

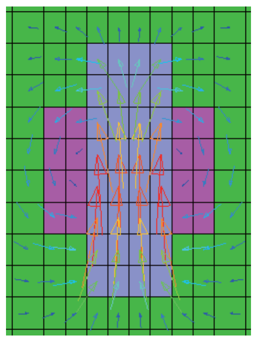

Fig.3 Magnetic flux density distribution of each element for the electromagnet model in Fig. 2.

FEA runs an analysis by applying Maxwell's equations to each element for the analysis model defining the geometry using mesh composed from many elements. As a results, an FEA analysis is run accounting for all of the phenomena, such as the eddy current distribution accounting for the flow of magnetic flux around conductors and the proximity effect in addition to the magnetic flux density distribution of magnetic materials and current distribution in conductors. The fundamental principle of FEA is directly applying the equations to a model of the analysis target to obtain the analysis results matching the measured values of a prototype.

An analysis accounting for the flux leakage is not impossible using the magnetic circuit method, but an analysis composing the magnetic circuit that accounts for the effects of the preliminary flux leakage is required. Therefore, the analysis accuracy varies according to the skill of the designer, but FEA can provide results without relying on the skill of the user because Maxwell's equations are applied uniformly to each element of the mesh generated for the analysis space.

2-c. Specifying the Material Properties

The magnetization properties change the output characteristics largely for devices including motors and transformers because they are constructed from magnetic material. The magnetization properties have nonlinear characteristics equivalent to the magnetic saturation. Analyzing the magnetization properties by accurately accounting for the nonlinear characteristics is vital to reproduce phenomena nearing the measured results.

An FEA analysis accounting for the actual magnetization properties using the nonlinear calculation method is expressed by the Newton-Raphson method (See Fig. 4). The magnetic flux density distribution when the complex magnetic flux density and excitation current varies with magnetic saturation can be obtained accurately because the

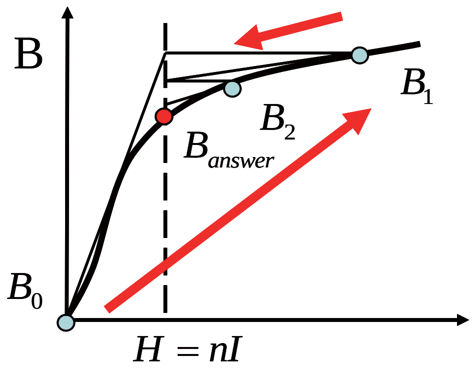

Fig.4 Convergence of the Newton-Raphson method

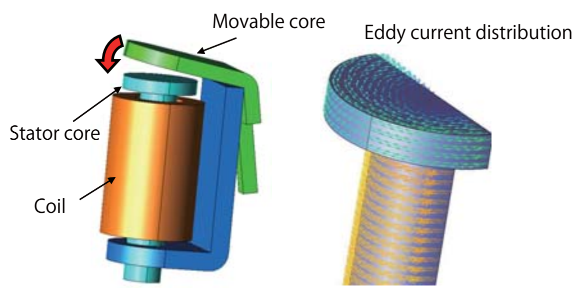

Fig.5 Eddy current distribution for a relay switch

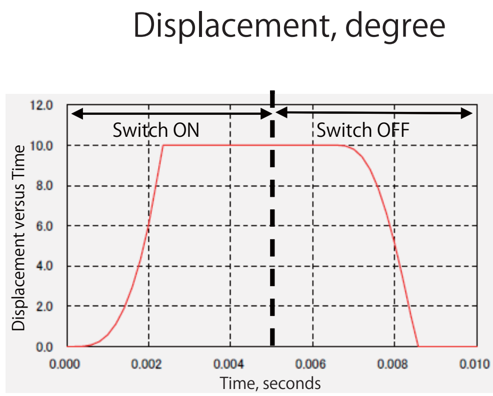

Fig.6 Response characteristics of the displacement for a relay switch

results are obtained for the operating points of each element.

An analysis accounting for the magnetic saturation, even for the magnetic circuit method, is achieved by preparing a table of the magnetic resistance of each magnetic material for each excitation force, but it does not offer the same flexibility as FEA that supports arbitrary magnetic properties. An analysis accounting for the eddy currents is also possible by specifying the electric conductivity of the conductors to handle phenomena produced by eddy currents in conductors while including the effects of eddy currents in the magnetic circuit method is difficult because the distributions cannot be calculated.

For example, the eddy currents produced in the core have a large effect on the response characteristics, such as relay switches. More will be introduced about this in the next issue. Qualitative evaluation becomes difficult for an analysis other than FEA when accounting for the eddy currents of the core in addition to the magnetization properties. The eddy current distribution and the response characteristics of the displacement for the core of the electromagnetic relay are indicated in Fig. 5 and Fig. 6.

These operating points are specific to the temperature dependency of the device because the effect of the raising temperature caused by the actual phenomena such as eddy currents. An analysis taking into account the temperature dependencies of the material properties, such as the electric conductivity, is necessary in these cases. Phenomena reproduced highly authentically when compared to the measured results can be expected because an FEA analysis accounting for the temperature dependency can be run by combining an FEA magnetic field analysis and an FEA thermal analysis. (There are also devices that proactively use the above phenomena including IH cookers)

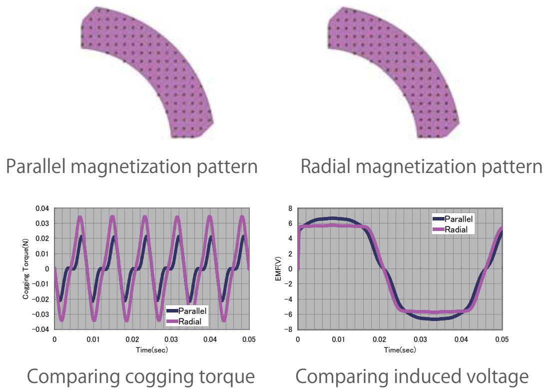

Fig. 7. Comparing the results for the cogging torque and induced voltage waveform

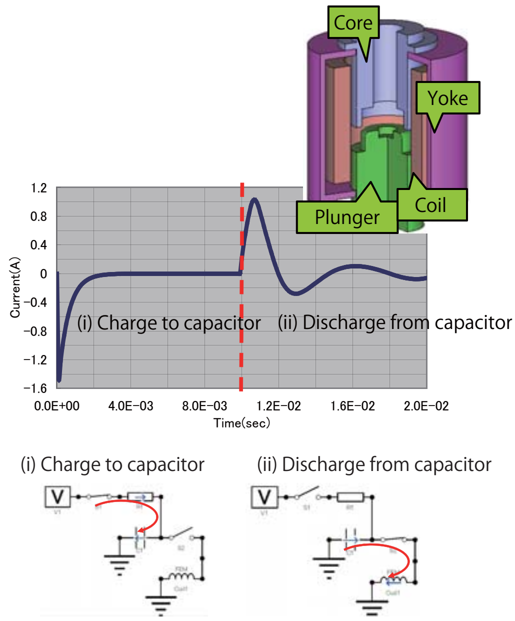

Fig. 8. Response waveform of current including a circuit (solenoid valve)

2-d. Specifying the Drive Conditions

The source of the magnetomotive force when handling electromagnetic phenomena is the magnets and current. Settings matching the actual operation environment and condition settings that have a high resolution are required to achieve a simulation that can authentically reproduce the physical phenomena.

The actual magnetization distribution can be reflected very near to the actual magnetization when using a magnet as the source of the magnetomotive force because the magnetization distribution can be defined by both the magnetization properties of the magnet and the complex magnetization pattern in each element using FEA. Simulations capable of high resolution settings such as FEA are vital to these evaluations because the magnetization of the magnets vastly affects the cogging torque waveform and the induced voltage waveform. Results comparing the cogging torque and the induced voltage when only the magnetization pattern of magnets in an SPM motor are changed is indicated in Fig.7. These results show a qualitative difference in the waveforms for varying magnetization patterns even though the magnetization is the same.

The current waveform is handled differently according to whether the waveform is known and unknown when the current is used as magnetomotive force. An analysis can be run by specifying the current values as values in a time interval table if the accurate time variations of the current are known. However, in most cases, a drive circuit including the power supply is attached to the analysis target and the current is determined by the analysis target as well as the drive circuit. An analysis using FEA that includes a circuit is required because the current waveform that needs to be specified is unknown in these cases. The circuit is closely defined using a circuit equation allowing an analysis to be run that comprehensively accounts for the drive by linking with FEA using Maxwell's equations to find a solution.

The time varying phenomena of the current before and after the charge and discharge of the capacitance when running an analysis of a solenoid valve including a drive circuit by linking to a circuit is indicated in Fig.8. The current following the LC vibrations caused by switching during the charge can be exported to a graph.

3 . Conclusion

As described above, FEA is an analysis method that can accurately reproduced the measured results from the characteristics.
FEA does not simply obtain the electromagnetic phenomena based on Maxwell's equations, but also easily includes the affects of speed electromotive force produced by accounting for motion. A simulation reproducing the actual operation can also be realized by combining an analysis with an external circuit.

In the next issue, the effectiveness of FEA will be specifically examined through actual analysis examples which fully utilize the features that are available.

Fully Mastering JMAG

Issue 1 Running Multiple Case Calculations from A to Z

Have you mastered JMAG?
JMAG is continually being enhanced each day. Even users who already know how to use JMAG may find some features they didn't even know existed. There are also many ways to go about operations that can provide even more convenience to the analysis process. Wouldn't you like to gain even greater efficiency through the new features and ways of using JMAG you didn't know existed?
This series introduces what users need to know about JMAG and how to use the software effectively.

Preface

Multiple calculations need to be run simultaneously to examine various designs. Therefore, a repetitive process requiring the same settings be specified over and over, multiple geometrical models with differing dimensions be created, and a large number of analysis results be organized. This repetitive procedure not only costs users time, but also increases the chance of simple mistakes like procedural errors or forgetting to specify settings.

JMAG offers a wide-range of useful features for running calculations with multiple cases to offer users a better design that comes to fruition faster. These features can benefit any user almost immediately.

Duplicate Studies to Change Only the Condition and Material Property Settings

Did you know that you could duplicate studies? The material properties and condition settings can be **duplicated** in a new study using JMAG. This allows an analysis model with differing material properties and condition settings to be created easily. A study can be duplicated using the following procedure:

1) Select the study to duplicate in the [Project Manager] treeview, and then right-click.
2) Select [Duplicate Study] > [Duplicate This Study] from the shortcut menu that is displayed.
3) A new study is added to the project.

Use Parametric Analysis for Values of Condition Settings in Addition to Geometrical Dimensions

Are you currently specifying multiple condition settings manually? JMAG can create geometrical models with differing dimensions, create analysis models with different settings, and run calculations if the base geometrical model is the same. This feature is the parametric analysis feature. The effect of design variables (numerical changes to parameters) on the analysis results can be evaluated simply using parametric analyses.

Design variables that can be used for a parametric analysis are the dimensions of the geometrical model and the various settings for the materials, conditions, mesh, and study properties.

A parametric analysis can be run using the following procedure:

1) Create a study using the standard procedure.
2) Register the dimensions of the geometrical model to change in the [Select Parameters] dialog box displayed from [CAD Parameters] under the study.
3) Register the other design variables to change in the [Select Parametric Parameters] displayed from [Case Control] under the study.
4) Specify the values of the design variables in the [Generate Parametric Cases] dialog box.
5) Confirm the cases to generate in the [Design Table] dialog box.
6) Right-click the study, and then run the analysis by selecting [Run All Cases] or [Run Active Case].
7) Confirm the variations in the response values for the design variables using a response graph.

Response graphs will be described in the next section.

Use Response Graphs to Evaluate Results for Multiple Cases Efficiently

Are you evaluating multiple results for comparison by using the same procedure to display the results again and again? The variations in the response values evaluated as design variables can be displayed easily based on the multitude of results obtained using a parametric analysis in JMAG. The process for comparing results including the average values, the maximum/minimum values, and the intensity is easy. This also allows the speed versus torque characteristics to be graphed right in JMAG.

A **response graph** can be created using the following procedure:

1) Display the graph of the response values to confirm
2) Select [Calculation] > [Response Graph Data] in the [Graph] dialog box, and then specify the title and calculation method.
3) Register the response values in the [Response Graph Table] dialog box.
4) Right-click [Graph] under [Response Graph] below [Results] in the treeview, and then set the X-axis and Y-axis in the [Response Graph] dialog box.
5) Display the response graph.

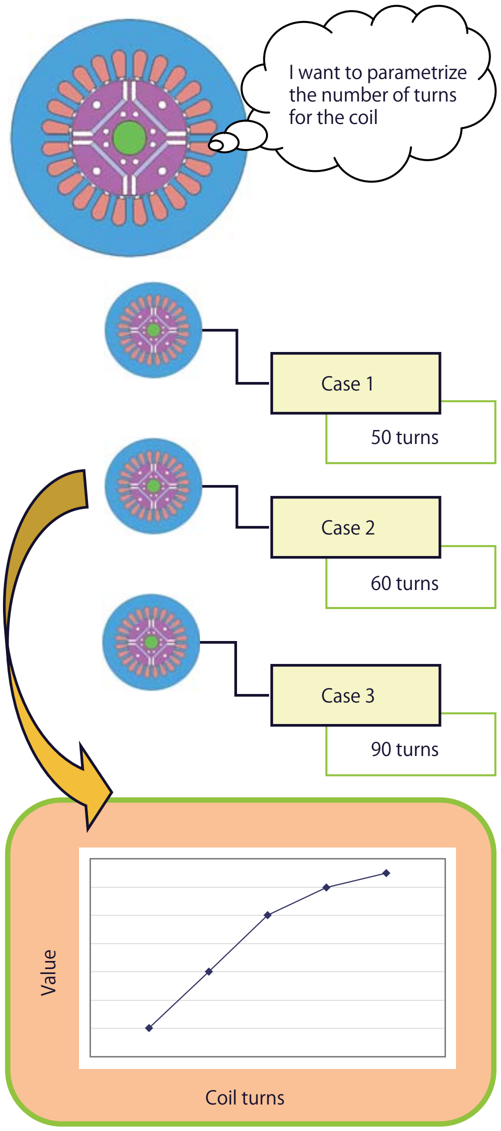

Fig. 1. Conceptual diagram of the parametric

Use Analysis Templates to Set the Same Conditions and Evaluation Items for Differing Geometry

Are you specifying the same settings repeatedly for different geometry? JMAG can apply the same settings automatically even if the geometrical model is different. Analysis templates can also be applied to evaluating results.

The **analysis templates** are a feature to create a template of the setting information including the existing analysis model that can be applied to different geometrical models. The settings that can be maintained are the configuration of the study, conditions, materials, mesh generation method, study properties, and the way to display the results. Setting can be maintained for faces, edges, and vertices in addition to parts.

An analysis using an analysis template can be run using the following procedure:

1) Create a study for the base geometrical mode, and then set the conditions, materials, and results display.

2) Right-click [Model] under [Project], and then select [Export Template].

3) Create a new project, and then import a geometrical model.

4) Right-click [Model] under [Project], and then import the template exported in Step 2.

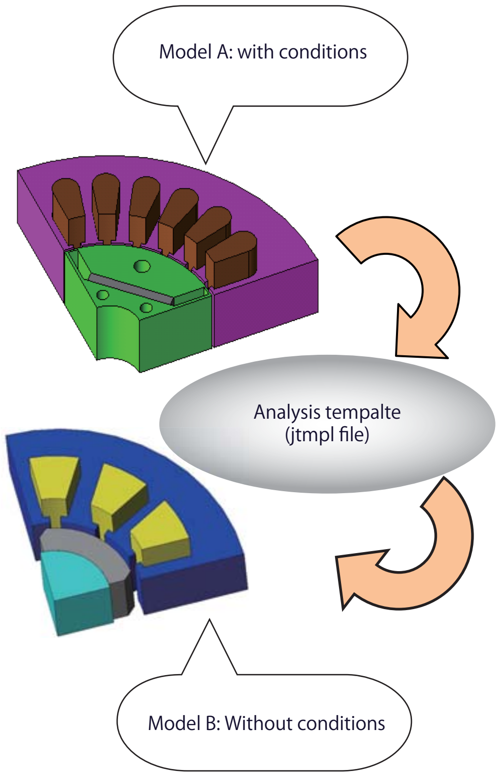

Fig. 2. Conceptual diagram of the analysis

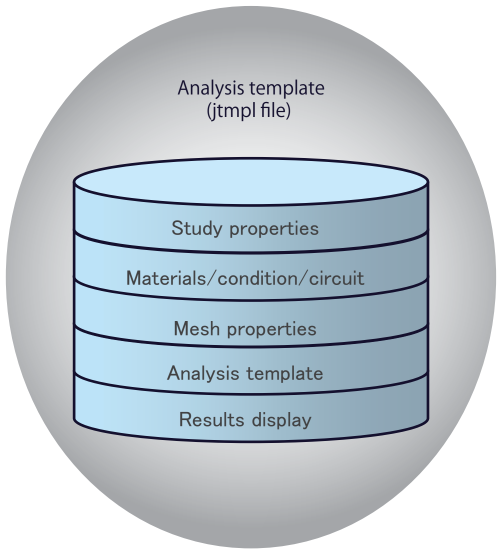

Fig. 3. Information included in analysis templates

Use the Script Feature to Automatically Run Standard Procedures

All of the features built into JMAG can be run using script. The **script feature** is useful for procedures that are often used.

Don't you think creating script is hard? The script does not have to be written manually. The script can be generated simply using the automatic script recording feature. A sample file is also provided in the installation folder for JMAG. Don't hesitate to try it out.

Script can be automatically recorded and executed using the following procedure:

|Recording Script Automatically|

1) Select [Script] > [Start Recording] from the menu bar to start the automatic script recording.
2) Perform the procedure in JMAG.
3) Select [Script] > [Stop Recording] from the menu bar to stop the automatic recording.

|Executing Script|

1) Select [Script] > [Script Editor] from the menu bar, and then open the script to execute.
2) Click the [Run] button in the Script Editor.

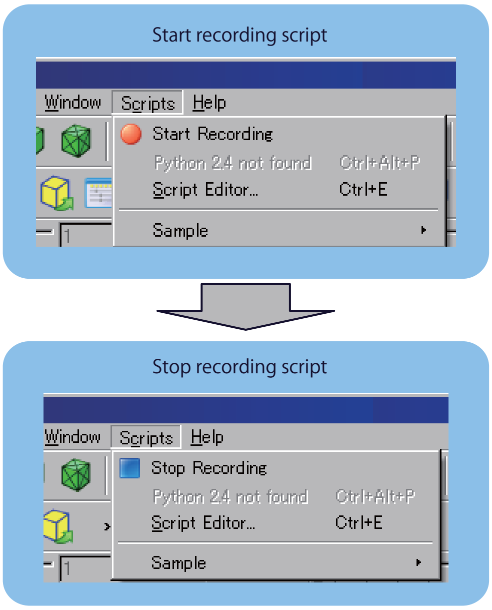

Fig. 4. Automatically recording script

Use JMAG-Scheduler to Run Batch Calculations

JMAG-Scheduler is used to run analysis independently from pre-post processing, sequentially run multiple studies or snapshot analyses. In addition, simultaneous calculations are now possible. This feature is great for running multiple calculations at once. Licenses for the number of calculations to run are required.

The procedure to run calculations simultaneously in JMAG-Scheduler is as follows:

1) Start JMAG-Scheduler.
2) Select [Settings] > [Number of Jobs] from the menu bar, and the set the simultaneous number of jobs.

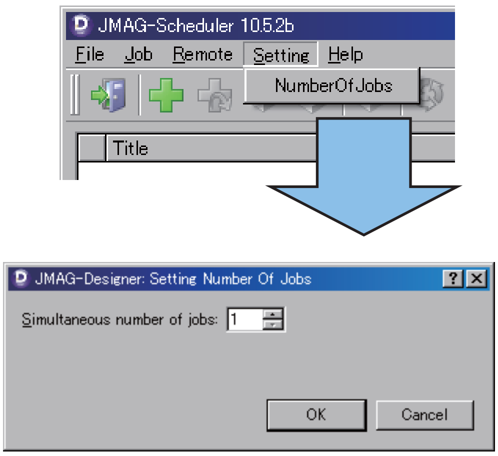

Fig. 5. Settings in JMAG-Scheduler

Use the "Remote System" to Distribute Calculations with Multiple Cases

The remote system can be used to improve the performance running multiple calculations using multiple machines.

The remote system is a system to run calculations jobs on another machine. A calculation can be run without loading down your machine by running that analysis on a different machine. A calculation can be run without loading down your machine by running that analysis on a different machine. The remote system in JMAG utilizes a client-server system. Therefore, the client is only used to submit jobs and acquire results.

The power of the client machine can even be turned off after submitting jobs because the jobs are managed on the server. Licenses are required for the number of calculations to run simultaneously.

For information about installing the remote system, see the Installation Manual. The Installation manual can be obtained as follows:

- The installation folder in the directory JMAG is installed.
- JMAG Website > Support > Download

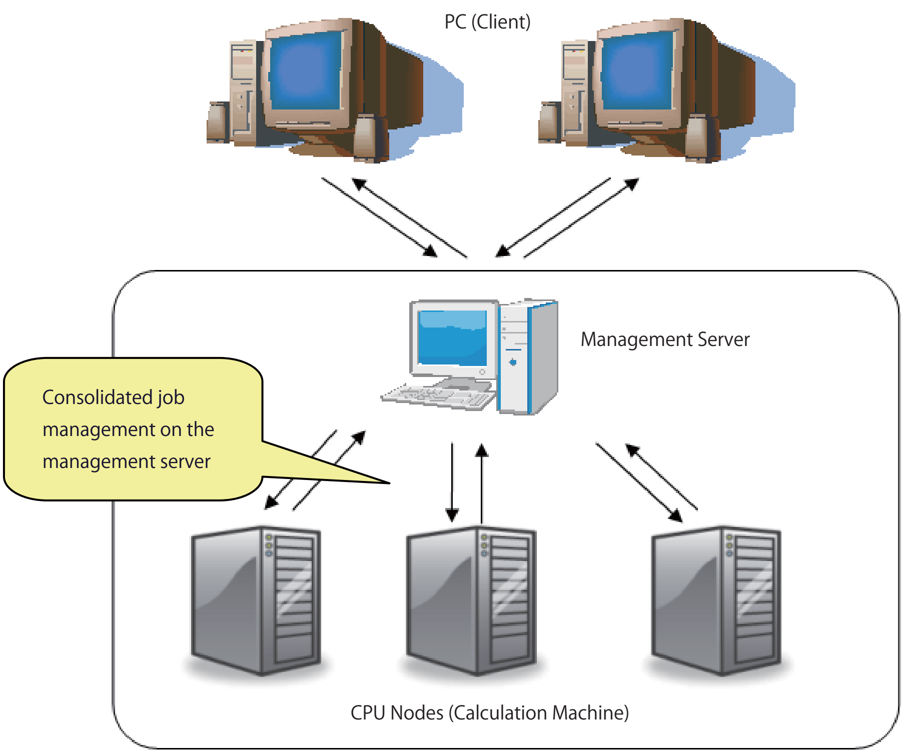

Fig. 6. Conceptual diagram of the remotes system

In Conclusion

This issue has introduced several useful features for examining multiple designs. Operations that were once difficult can be performed much easier now. Please don't hesitate to use the features offered in JMAG to reduce the time costs and prevent mistakes in the settings.

In the next issue, some surprising unknown and useful features will be introduced focusing on operations for basic applications. We hope you enjoy it.

Terminology

[Case Control]
[Case Control] is at the heart of parametric analysis. [Case Control] is used to add and manage cases as well as design variables.

[Study]
A study is used to manage the necessary elements of an analysis including the conditions, materials, mesh, and analysis results in JMAG-Designer.

[Snap Shot Analysis]
A snap shot analysis is a feature to obtain results very quickly by distributing an each step of an analysis with multiple steps to multiple machines over a network.

Mini Corner
“How do I resolve ‘trouble’ encountered in JMAG?”

Have you ever encountered trouble while using JMAG? How did you resolve the problem when it occurred? Everyone has their own way of addressing these problems from asking other JMAG users around them, contacting support to looking into the problem further or eventually just having to give up.
JMAG offers a wide-range of support services to solve "trouble" encountered while using JMAG. This section introduces the support services for each aspect when using JMAG that we would like you to know are available.

■ "Trouble" During the Installation
Installing software seems like an easy process, but understanding how to set up the license, etc., and often be difficult. A simple procedure for installing the software is as follows:
(1) Prepare the license information.
- The license information is sent by email.
- The license server information is also required if the license server is configured on a machine other than the machine running JMAG.
(2) Install JMAG following the instructions displayed in the installation program.
- The license settings are specified following the installation.

URL： http://www.jmag-international.com/