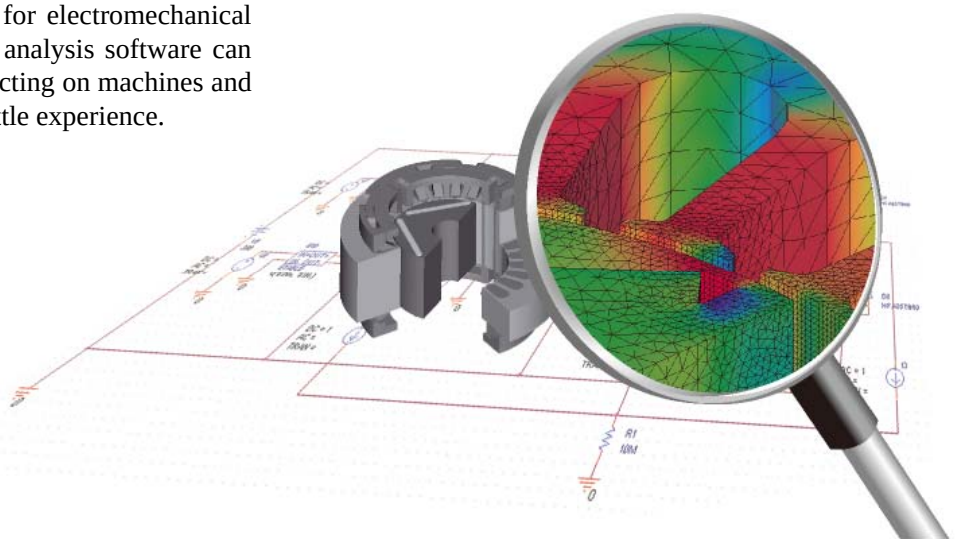
Simulation Technology for Electromechanical Design

JMAG

JMAG News Letter

Spring. 2011

JMAG is a comprehensive software suite for electromechanical design and development. This high speed analysis software can capture the complex physical phenomena acting on machines and obtain highly accurate results easily with little experience.



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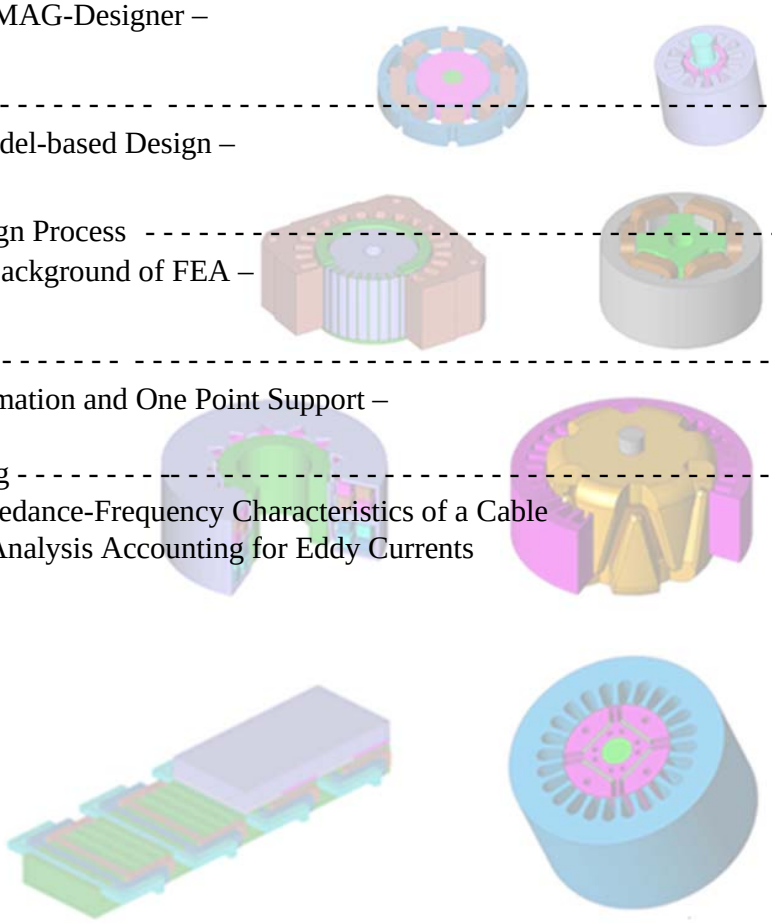

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JMAG News Letter Spring Edition

The Spring Edition of the JMAG News Letter brings with it even more information than before.

A series of articles will now be included to explain both model-based design and finite element analysis (FEA). The JMAG News Letter is valuable for everyone from those currently using JMAG or those just starting to use JMAG or even anyone that is not presently using JMAG.

Please don't hesitate to share the JMAG News Letter with everyone around you that are just starting out using JMAG. Let’s take the journey into FEA and model-based design together.

In this edition, we interviewed the SIM-Drive Corporation headed by Hiroshi Shimizu, the pioneer of electric vehicle development in Japan as the Professor in Faculty of Environment and information Studies at Keio University. The SIM-Drive Corporation discusses their unique business model and ongoing efforts in developing in-wheel motors that provide a good driving experience, or more specifically, acceleration and low vibration.

The product report focuses on the CAD link features. JMAG-Designer provides a wide-range of innovations capable of analyzing CAD models that are imported in a feasible amount of time. This report also introduces the features used to analyze the data that is imported in addition to the CAD link features.

This edition of the JMAG News Letter is packed with more information than ever before. We hope you find the information in this edition of the JMAG News Letter valuable.

JSOL Corporation
Electromagnetic Engineering Department
Engineering Technology Division

Implementing JMAG

SIM-Drive Corporation

Leading Motor Development for Mass Production Electric Vehicles

The SIM-Drive Corporation (headquarters: Shinkawasaki, Saiwai-ku, Kawasaki-Shi) establishes joint development projects for the mass production of electric vehicles (EV) using their vast experience and accomplishments in EV research. Hiroshi Shimizu, the pioneer of EV development in Japan as the Professor in Faculty of Environment and Information Studies at Keio University, heads the research and development as the Chairman of the SIM-Drive Corporation, a venture company. Osamu Shimizu from the In-Wheel Motor Propulsion Development Division related to the development of motors for electric vehicles discusses the current trends of EV development and how the SIM-Drive Corporation uses JMAG.

Osamu Shimizu
In-Wheel Motor Propulsion
Development Division
SIM-Drive Corporation

Unique Open Source Development System

- The SIM-Drive Corporation is known for furthering the development of electric vehicles as its business model. How does this business model work?

Mr. Shimizu Hiroshi Shimizu, a Keio University Professor and Chairman of the SIM-Drive Corporation, has made it our mission to provide the best technology and information for electric vehicles based on more than 30 years of knowledge and research for electric vehicles to related industries at the lowest possible price. We use an *open source* method to achieve this goal.

In other words, we establish joint development partnerships for a fee of 20 million yen for each development project we undertake for new electric vehicles. Our joint partners can be involved in all aspects of prototyping for the project and we provide the specifications, basic plans, and official copies of the testing results after the vehicle development is complete. Our joint partners are able to reduce their lead time and have access to the latest technology while we can devote ourselves to the technological development of electric vehicles.

34 companies and organizations invested and participated in our Advanced Development Project 1 that started in December 2010. Our first vehicle was completed in March 2011. Our second Advanced Development Project started in January 2011 with the support of 34 companies and organizations.

- What is Professor Shimizu's development philosophy and what points of technological development does he focus on?

Mr. Shimizu The name SIM-Drive comes from the first letter of each word in the phrase "Shimizu In Wheel Motor-Drive." SIM-Drive includes all of the components and technology revolutionized for electric vehicles that have been developed by Professor Shimizu. More specifically, the SIM-Drive Corporation researches and develops drive systems composed of high performance in wheel motors, inverters, and batteries for component built-in frames. These technologies are not only limited to ground up models developed from scratched, but also focused on technology that can be applied to existing vehicles. The electric vehicles using components approved by SIM-Drive are identified as *by SIM-Drive* or *platform by SIM-Drive*.

The Advanced Development Project 1 that used this type of drive technology ran for 333 km on a single charge, which cleared our goal of cruising more than 300 km (JC08 mode = standard driving in a city for Japan). The capacity of the batteries that are used is almost the same as the capacity of the batteries used in EV on the market today, 24.9 kwh,. The AC electric power consumption of 77 Wh/km (watt hour/km) is equal to 1 litter of gasoline consumption, which corresponds to the energy consumed to run 70 km.

Advanced Development Project 1

High Performance is Achieved from In Wheel Motors and a Hollow Structure

- What are the in wheel motor and component built-in frames that are at the core of this technology?

Mr. Shimizu In wheel motors are motors that are installed in the wheel of vehicles that allow regeneration breaking when the motor accelerates or breaks by directly driving each wheel in addition to a dramatic reduction in the energy lost when power is transferred to the wheels from the motor. The energy that is used is reduced by 30 to 50 percent compared to on-board type vehicles that have the motor installed in an engine compartment, there is no transmission system for torque required, and there is more space allotted for the cockpit because of the simple structure that eliminates a motor in the engine compartment.

There are two types of motors; *gear reduction motors* and *direct drive motors*. The Advanced Development Project 1 utilizes an outer rotor type direct drive motor. These motors have a rotor with magnets arranged on the outside of a stator that coil is wound. There are small, mid, and large scale versions of these motors, but our research and development currently focuses on 65 kw large scale motors. One of the primary features of the SIM-Drive Corporation is developing vehicles that combine small, mid, and large scale motors based on the size, shape, and purpose of the vehicle.

The component built-in frame is technology where the main components, such as the batteries, are installed in the hollow area of the frame that has a robust hollow structure under the vehicle floor. An image of this technology would be a toolbox in the wheel area. The amount of space that can be used for the body of the vehicle is increased offering more freedom to the design and furthering the miniaturization of vehicles. This design also provides a safer driving experience because the center of gravity is lower. As I mentioned before, one of the main features of the SIM-Drive Corporation is applying technology to existing vehicles, which the component built-in frame allows us to do. For example, a used luxury vehicle could be converted into an electric vehicle.

- How does SIM-Drive use JMAG?

Mr. Shimizu The in wheel motor is really the heart of SIM-Drive's technology. There are a wide range of aspects demanded of vehicles from the cruising distance to acceleration and low vibrations, which are all related to the innovation of motor technology for the EV. Analysis using JMAG is indispensable in the development and refinement of this technology.

For example, we built roughly 200 models as prototypes for the Development Project 1.Building the same number of actual prototypes would be require too much time and be too costly.

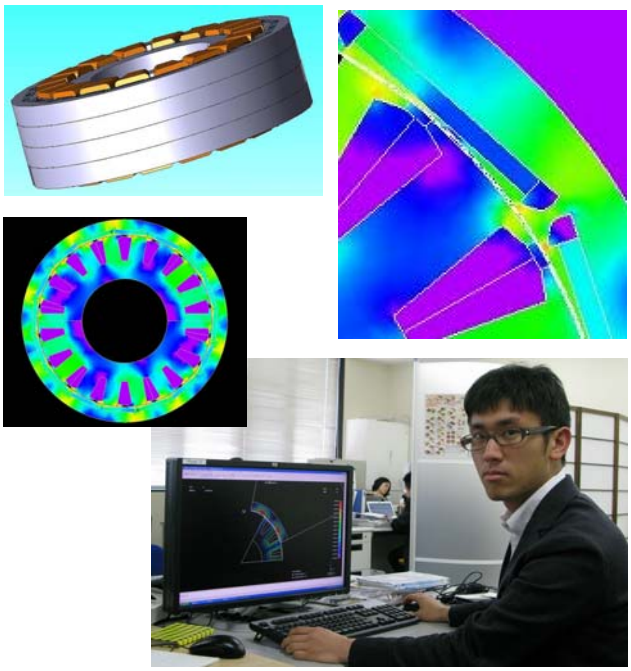
Being able to thoroughly examine the high performance during the development process is expanding around JMAG. Japan currently leads the world in the development of electric vehicles, but the competitive edge is gained by knowledgeable research and development teams that fully utilize tools like JMAG to provide the top motor technology to the rest of the world.

We also work in a system with our joint partners that invest in a development that centers around JMAG. For example, if our joint partner is a material manufacturer, they will provide data in a format that we can use in JMAG for material property data. Our EV development policy generally focuses on technology that uses common materials. Furthermore, the results obtained using JMAG provide invaluable evidence that gives us a strong negotiating position because we can show that a design is achieving the desired goals using these analysis results when moving forward to build the actual prototype.

Furthering Leading Edge Technology by Standardizing These Tools

Why did you start using JMAG?

Mr. Shimizu JMAG was first implemented in 2004 in Professor Shimizu's research laboratory at Keio University, not at the SIM-Drive Corporation. At the time, they had succeeded in developing an EV prototype and they implemented JMAG as a development and analysis tool for drive motors. They chose JMAG because it was easy to use. The user interface was clear and straightforward and they didn't need to worry about entering mathematical functions. JMAG was also extremely powerful as a software, which is probably an obvious reason for choosing it.



Motor analysis in JMAG

JMAG is also been used by many companies and has become a standard in the industry as the electromagnetic field analysis software in the field of motors. The results can be utilized in a wide-range of other analyses because JMAG has become the standard in the industry. Japan provides the leading-edge motor technology in the world for electric vehicles because Japan is using analyses. The technology keeps advancing by combining design, analysis, and manufacturing using world-class fabrication of components.

- What do you hope JMAG can offer in the future?

Mr. Shimizu Users are a tough breed of people that will never be satisfied and they will always have complaints (Mr. Shimizu laughs). First, I would say that the terminology used for electromagnetic field analysis, which is obviously difficult, could be made simpler. The freshmen that are allowed to join the research laboratory at Keio Universities' Shonan Fujizawa Campus become proficient with JMAG very quickly because it is so easy to use. However, they lack the understanding of the terminology surrounding the electromagnetic field analysis.

Although I may be asking for too much, I would like to have a place where there is a greater exchange of technological information related to the efforts and know-how of analysis from the companies and organizations using JMAG, such as how they run analyses and evaluate the analysis results. Of course this type of information is what allows companies to stay competitive, and it is not something that can be easily disclosed, but I hope that that the JMAG team can show them the value in presenting at conferences and gatherings related to analysis software.

- I am sure everyone is very interested in the Advanced Development Project 2. Do you mind telling us a little about the focus of that development?

Mr. Shimizu The Advanced Development Project aims to make the mass production of electric vehicles a reality by 2014. We believe that more highly efficient in wheel motors is the technology that will make this happen. I cannot go into detail about our current development, but we are focusing on a smaller motor that can rotate longer, or in other words, drive longer distances. The Advanced Development Projects generally last about one year and we need to complete our second prototype by next spring.

TECO Corp., a large electronics manufacture in Taiwan, is already planning a production line that aims to manufacture 100,000 units in 2013. The SIM-Drive Corporation is contributing to that development, but we hope that the mass production will be established as soon as possible to address the environmental problems of the world today.

SIM-Drive®

Company Name	SIM-Drive Corporation
Established	August 2009
Location	KBIC 7-7 Shinkawasaki, Saiwai-ku Kawasaki-Shi, 212-0032 Japan *The headquarters has moved
Capital	99 million yen
Officers	Chairman: Soichiro Fukutake (Chairman of Benesse Holdings, Inc.) Director: Hiroshi Shimizu (professor in faculty of Environment and Information Studies, Keio University)

Business Activities

Research and development of electric vehicles

Research and development of in-wheel motors for electric vehicles and other parts for electric vehicles

Consulting pertaining to the development of electric vehicles

Support for basic production of electric vehicles

http://www.sim-drive.com/

Product Report

CAD Link Features in JMAG-Designer

These product reports focus on the features of JMAG. This product report takes a look at the CAD link features realized by JMAG-Designer (hereinafter referred to as JMAG)

● Preface

Product development, not limited to electromechanical machines, originates from determining the geometry of the product for the required specifications. In most cases, current trends for the geometry design use CAD. CAD is an indispensible tool to support the process for improving the geometry of a design and finding the easiest geometry to manufacture that has good performance. The object of using CAE is to evaluate whether the geometry design fulfills the requirements and whether or not there is a better design based on the feedback obtained from the analysis for the design. Therefore, the tools related to product development are expected to be highly compatible with CAD. Analysis tools are also expected to run analysis directly using the CAD data (geometrical information).

CAD link features are necessary for a more efficient development process because the more advanced the links between CAD and CAE the more advanced concurrent development becomes shrinking the loop of development and increasing the speed of the design process. This report focuses on the features to link JMAG and CAD, but the Geometry Editor built into JMAG can also be used as CAD for anyone that has not presently using a CAD system to run analyses using the CAD link features.

● Improving Compatibility with CAD for JMAG

JMAG is based on the concept of being "OPEN" and features are continually developed to improve the compatibility with CAD. First let's look at the basic feature for importing data created using CAD. The process of reworking a new geometrical model for an analysis decreases the efficiency of development and inhibits the use of CAE. A CAD data converter is available in JMAG to import geometrical data exported from a wide range of CAD systems. As a standard feature, 3D geometry can be imported as SAT data and 2D geometry can be imported as DXF data. Furthermore, the proprietary converter available for JMAG supports CATIAv5, CATIAv4, Pro/ENGINEER, and IGES-3D.

The CAD link features achieve a concurrent process that links JMAG and CAD in addition to simply importing the geometrical data. More information is provided later, but this allows the geometrical information to be shared between CAD and JMAG. Changes to the geometry in the CAD data can be sequentially reflected in the input data for CAE because the material properties and condition settings managed in CAE for the geometrical information (solids, faces, and edges) managed in CAD are maintained when a link is established. The converter required to share the geometrical information in CAD with CAE was developed to realize this feature.

Using an actual user case as an example, a magnetic field analysis of the magnetic circuit geometry for the layout design created in CAD was run to evaluate the magnetic saturation as well as unnecessary magnetic pathways. These results were then reflected in the geometry design in CAD, and then the cycle was repeated by evaluating the new geometry using another magnetic filed analysis.

Presently, the CAD systems that JMAG supports are CATIAv5, Pro/ENGINEER, NX, and SolidWorks.

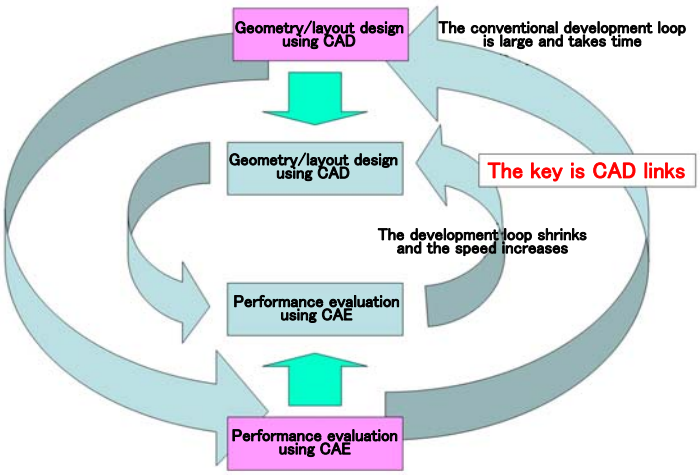


Fig. 1. Process to achieve a CAD-JMAG link

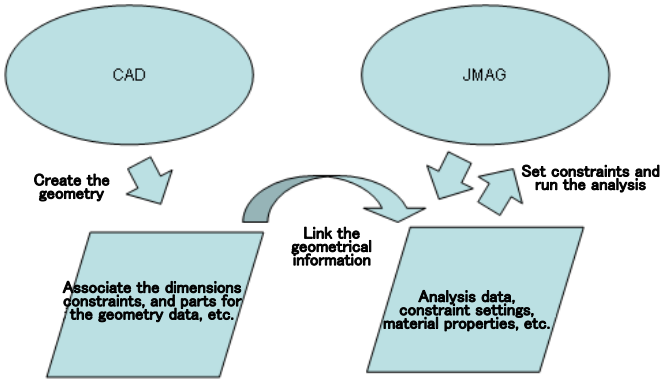


Fig. 2. Data configuration of the CAD-JMAG link

Advancing CAD links with JMAG-Designer

The features of JMAG are developed with a strong focus on CAD link analyses. The benefits of the CAD links are taken one step further by not only linking the data, but also providing analysis features.

(1) Section Analysis

Unfortunately, even though the speed of analyses have improved drastically, time is still required to run 3D magnetic field analysis, making it unsuitable for rapid analyses during the beginning stages of an evaluation. Using a 2D analysis to refine and determine the validity of a design before running a 3D analysis is usually the flow of a simulation, especially for machines that can be evaluated using a 2D analysis. However, this means a 3D model and a 2D model need to be created to use 2D and 3D analyses. This extra work is seen as being unnecessary from the point of view of the geometry design.

JMAG provides a *Section Analysis* that allows an appropriate 2D analysis cross-section to be extracted from 3D analysis data to address this problem. The material settings and the boundary conditions are shared between the 3D and 2D models, just as the CAD geometry is shared between CAD and JMAG. Designs can be refined by running multiple 2D analyses using this feature, and then finalized by running a 3D analysis. The geometry of the design can also be examined even further by returning to the 2D analysis to efficiently and accurately finalize the design.

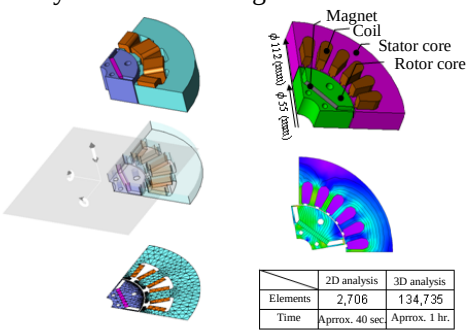


Fig. 3.Section analysis

(2) Analysis Templates

Often the design process is a repetitive routine. An engineer designing a motor one day vary rarely designs a transformer the next day. Therefore, the condition and material settings that are often used and the desired analysis results excluding unnecessary physical quantities often overlap. The analysis template feature in JMAG addresses this need. A template including the necessary material and condition settings as well as the results to display for an analysis can be created. The analysis data that is often utilized can be exported as an analysis template.

The condition and material settings requiring the users attention can be contextualized by applying an existing analysis template to a model linked to CAD or geometrical data that is imported as a file. Furthermore, the settings, such as conditions, are automatically linked by establishing a rule for using the same names for parts in the CAE data because JMAG offers a feature to link the settings based on the name of parts. This feature makes a process that was conventionally handled using script easy to use. Analysis policies and standards for evaluations can be standardized and one's expertise pass to other designers by sharing the analysis templates.

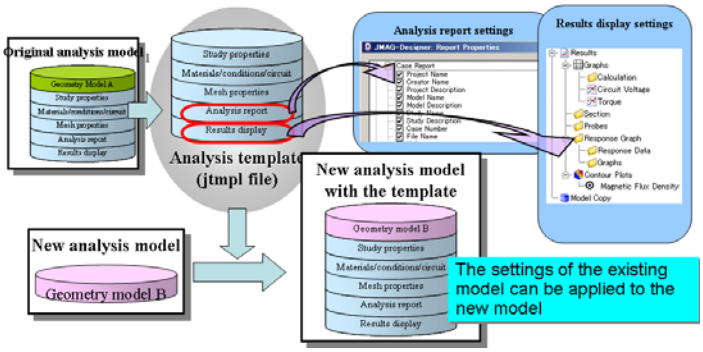


Fig. 4.Using analysis templates

(3) Parametric Analysis

Creating a design (judging a design) is the process of finding the optimal characteristics by combining various parameters under the limitations of design. Whether or not a design meets the requirements using various analysis conditions can be determined using a parametric study. For this reason, multiple analyses need to be run by combining various geometry, material properties, and analyses conditions.

JMAG offers a parametric analysis feature to efficiently run parametric studies A parametric analysis can be run easily by parametrizing settings such as the discrete values for the current, voltage, rotation speed, and material properties used for an analysis. The degree of freedom is even greater for the geometry use for a parametric analysis using SolidWorks or the JMAG Geometry Editor because dimensions of the geometry are shared allowing JMAG to control the geometrical dimensions in CAD.

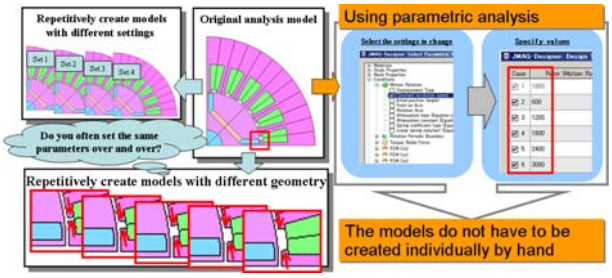


Fig. 5..Parametric Analysis

(4) Mesh Generation

Mesh is vital as a parameter which determines the analysis accuracy for the CAE finite element method used in JMAG. The mesh generation features in JMAG are also developed recognizing the CAD link to increase the success when generating mesh for various geometrical models.

For example, defeaturing contributes to improving the stability of the mesh generation and reducing the calculation cost by recognizing and removing detailed geometry that is unnecessary for an analysis, such as C chamfers and screw holes. JMAG also provides a feature to generate symmetrical mesh automatically by identifying the regularity of geometry, which is extremely effective in improving the accuracy of rotating machines. The appropriate mesh can be generated and an accurate magnetic field analysis performed even if the user is not familiar with the program. There are also various control functions for the mesh generation to further increase the accuracy. The element size of solids, faces, edges, and vertices can be specified, mesh simulating the skin effect can be generated, and mesh morphing can modify the geometry directly using the mesh.

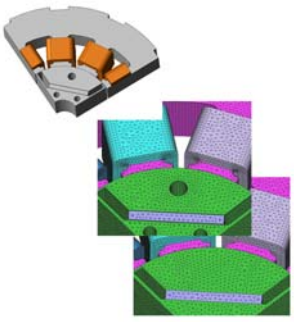


Fig.6.Mesh generation

(5) Drag-and-drop Operations

The efficiency of the development process would not improve if the operation in JMAG was complex. For this reason, JMAG provides an intuitive user interface. The material properties and the condition settings can be specified using drag-and-drop operations with the mouse. The settings panel opens when the mouse button is released, and then the settings can be specified by selecting items from a list or entering numerical values in the text boxes. Each of the settings panels links directly to information in the manual through a help button so there is never any confusion about the settings. Warning features built into JMAG caution users when the settings are incomplete. In addition, the magnetization and iron loss characteristics of materials that are vital to analyses are implemented as a database.

The stress of running analyses is further reduced because the materials can be set by selecting from materials cataloged by the material manufacturers.

The settings can be changed and modified easily because all of the specified settings are clearly displayed in a treeview.

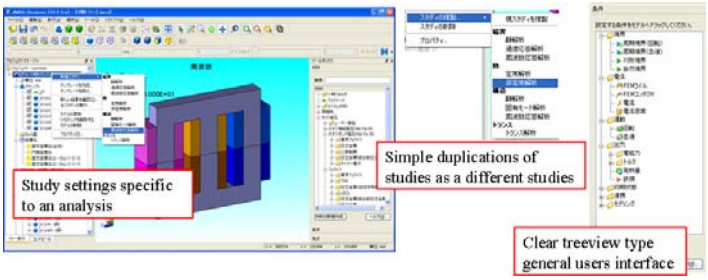


Fig. 7.Drag-and-drop operations

(6) Geometry Editor in JMAG

The previous section discussed challenges assuming users that have implemented CAD, but the CAD link features in JMAG can be used by anyone that does not have a 3D CAD system using the Geometry Editor built into JMAG. JMAG's Geometry Editor can be used to create 3D data for the parts required to run an electromagnetic field analysis easily. The geometry editor can be thought of as a light weight CAD system. A powerful CAD link analysis feature can be achieved by linking the Geometry Editor and JMAG.

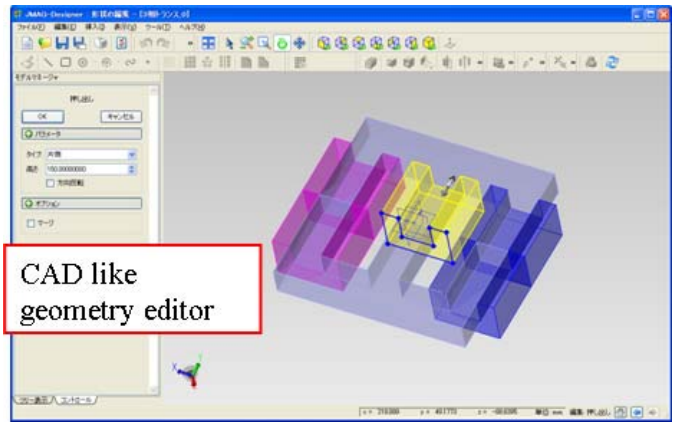


Fig. 8. Geometry Editor in JMAG

Operating JMAG When Using CAD Links

The actual flow to use a CAD link is as follows:

(1) Prepare a machine that has CAD, JMAG-Designer, and the CAD link features installed.
(2) Start JMAG. Import a CAD file after JMAG starts.
(3) Establish a CAD link.
(4) Specify the condition settings for the model that is imported into JMAG.
(5) Run the analysis, and then evaluate the results in JMAG.
The procedure up to this point is pretty standard. The effectiveness of the CAD link can be exhibited in the following process.
(6) Edit the geometry in CAD, and then update or replace the model in JMAG.
(7) A new model that still has the conditions specified after the geometry has been modified is added if the model is updated.

Expanding Possibilities Using CAD Link Features

New avenues for design become available because of the high compatibility between CAD and JMAG. Optimization is one example. As you know, optimization software is a tool used to support designers in finalizing designs. The design variables and design proposals defined by the designer are prioritized, and then the optimal design can be flushed out. This frees the designer from simple daily chores and allows them to be more creative and productive.

However, the full potential of the optimization software cannot be taken advantage of if the compatibility between CAD and CAE is weak because the interface becomes cumbersome between the software, more preparation is required, the operation is unstable, and unnecessary evaluations are performed. In other words, high compatibility between CAD and CAE is required to use optimization software to the fullest extent. The optimization software can be utilized even more by merging the robust geometry features of CAD and the highly accurate analysis features of JMAG with optimization tools. JMAG also has direct interface capabilities with the optimization software ModeFRONTIER and Optimus. Other optimization software can also be supported by creating script to use in JMAG.

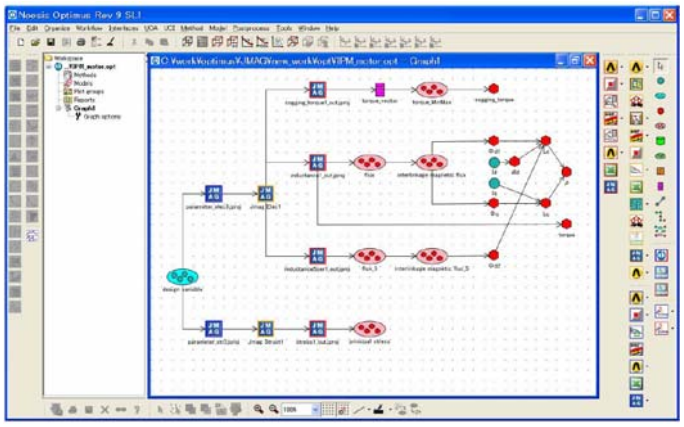


Fig. 9. Linking to optimization software

JMAG for CATIA V5

In addition to the CAD link features that have been introduced, *JMAG for CATIA V5* provides the JMAG magnetic field analysis right inside CATIA V5. For anyone currently using CATIA V5, the design through magnetic field analysis cycle can be performed directly in CATIA V5 by implementing *JMAG for CATIA V5*. The user interface will be familiar to CATIA users because JMAG for CATIA V5 was developed with the same design as a CATIA add-on.

The analysis data that is created can also be imported into JMAG to perform even more in-depth analyses.

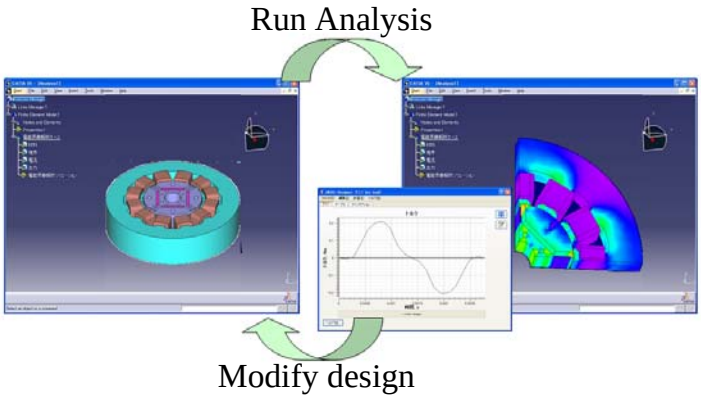


Fig. 10.JMAG for CATIA V5

This product report has introduced the CAD link features available in JMAG. The CAD link features achieve an efficiency in the design process that cannot be realized by simply importing CAD files.

JMAG is continually developed to reinforce these features to provide even more robust CAD link compatibility. Don't hesitate to try it today.

Model-based Design

Efforts in JMAG for Model-based Design

Recently, *model-based design (development)* is a term starting to be used in the development process. These reports discuss what model-based design is and how it is related to you in addition to how JMAG is utilized in model-based design. This report introduces the fundamental characteristics of model-based design.

● Evolution of Model-based Design

The system development of automobiles is a primary example of when model-based design is often used in actual development.
Units, such as the transmission, power steering, ABS, and drive control, are all controlled electrically by the software built-into the ECU making the electrical control of the engine a type of computer. These complicated ECU need to be examined to realize a system that moves as the driver desires while connecting these units.

Of coarse, all of these units can be examined using a prototype vehicle, but the rework required when a defect is discovered could be immense. Front-loading development related to examining each units independently as well as at a system level is vital to reducing the cost and risk of development.

This solution is referred to as *model-based design*.

Model-based design is a method to evaluate a system (plant) by expressing each unit as a model and simulating the interface between each model virtually on a computer.

Model-based design is advantageous to evaluate the entire system as the time lag of a single unit can have devastating effects to the entire system in the ECU used for communication.

Model-based design may be a new term, but the actual concept has been around and is simply an extension of current processes.

In the past, information about parts was offered as diagrams and specifications. The system engineer would create the layout design based on these diagrams and manually calculate the performance and quality. In this case, the *diagram* equals the *model*.
However, the information that used to be provided in diagrams is now offered as *three-dimensional data* following the standardization of 3D CAD.

The concept of providing this information as a model has not changed even though the three-dimensional data now used as the model.

Exchanging the information as a diagram may seem like a method used a generation ago now that using the three-dimensional data has become the expected format, but the idea is still the same.

The geometry has evolved from two-dimensions on paper to three-dimensional digital data vastly increasing the amount of information, which in turn increases the expectations for higher performance.

How will the machine operate if I apply voltage? The designs are now performed knowing how much performance can and cannot be achieved.

Model-based design will also become a process everyone will learn, just as the geometry has evolved.

● Solutions for Model-based Design in JMAG

One of the solutions for model-based design provided by JMAG is *JMAG-RT*. The origin of the name steams from the goal of "support for JMAG in Real Time Simulations," which is the ideal for model-based design.

JMAG is capable of obtaining highly accurate magnetic field analysis results for electromechanical machines. Therefore, it has been conventionally used as a tool to further the designs created by the electromechanical engineers.

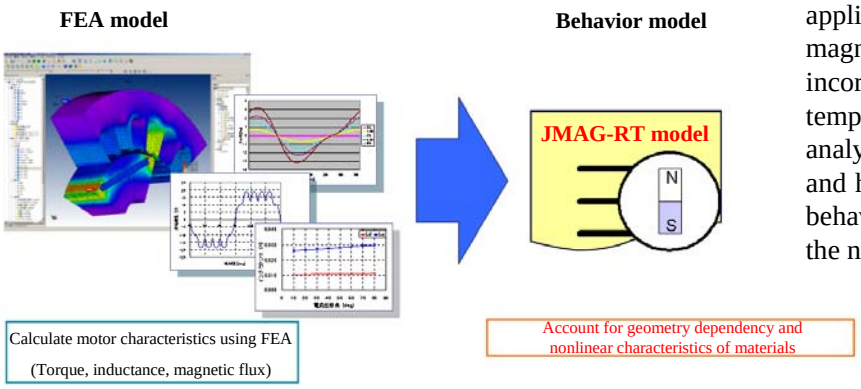
However, electromechanical machines, such as motors and transformers, start to operate only after power is supplied by a drive circuit and the relationship between devices cannot be ignored. For this reason, the electromechanical design needs to be shared with the circuit and system designers.

JMAG-RT was developed as a tool to transform the analysis results into a highly accurate model to provide a solution to share this information.

For example, conflicting objectives including miniaturization, higher output, higher efficiency, higher quality, better control, and lower costs are required for motor development. This means that the nonlinear region of the magnetization characteristics have to be used resulting in the development of motors that are hard to handle from the inverter side.

The key to development is knowing the final objective of the designs because the inverter itself is also under the same demands as the motor.

Simulations using models that express the behavior like a prototype are required so that the final objective of both designs overlaps.

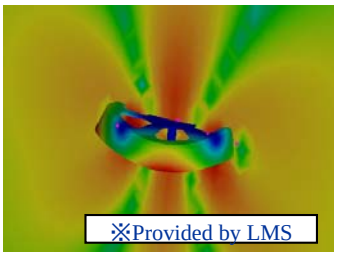


JMAG-RT is a tool that has already been used by many designers to convert the electromechanical machine into a model that can be utilized in the circuit/control simulator (behavior model).

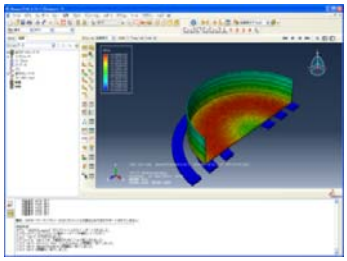
JMAG-RT is evolving to satisfy the needs of the market.

Models of induction and SRM motors will be added to the PM, stepping, and linear motors that are currently available.

A feature to incorporate iron loss in the PM motor model will also be added.



Noise analysis using LMS Virtual.Lab



Induction heating analysis coupling JMAG-ABAQUS

Model-based development is not limited to the control and electric circuit. JMAG is also continually improving performance through interfaces to third-party applications allowing vibration/noise evaluations using magnetic field and structural analysis models incorporating electromagnetic force and stress as well as temperature analysis using thermal and magnetic field analysis models incorporating current heat generation and heat to be performed easily. Thermal and structural behavior models will be developed in the future to meet the needs of the market.

This report has discussed the concept of model-based design and the efforts of JMAG toward model-based design. The next report will focus on the new feature of JMAG-RT to be released at the end of June.

Impact of FEA on the Design Process

Issue 1 Prevalence and Background of 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.

● Before FEA

FEA is well known as an analysis method using a computation solver. In recent years, the utilization of specialized computation solvers for FEA in the development process is not unusual. Furthermore, large scale analyses exceeding a million elements or analyses that have multiple cases are being used more frequently. However, this was not the case a quarter of a century ago due to the limitations and cost of the computation solver performance.

Therefore, how did FEA enter into the development process as a design tool at that time?

The simple answer is years of intuition and experience. However, the magnetic circuit method has been used systematically as the primary method to analyze the magnetic characteristics of electromechanical machines. The magnetic circuit method is a universal analysis method that is used widely even today, but, it was the only analysis method available at the time because the computation solvers were not as sophisticated as they are today.

The magnetic circuit method is a method to estimate the magnetic flux produced in the magnetic pathways of the magnetic circuit by replacing the core, coils, and magnets making up a machine with a magnetic circuit composed of the source of magnetomotive force and magnetic resistance. An example of a magnetic circuit overlayed on a motor is indicated in Fig. 1. This method can be calculated by hand without a computation solver because large scale calculation is not required for a simple magnetic circuit. The electromagnetic attractive force between the stator and mover obtained using the simple magnetic circuit method for the solenoid value shown in Fig. 2 is indicated in Fig. 3. In Fig. 3, the calculation results using FEA are compared to the simple magnetic circuit method to show the similarity of the results regardless of which method is used.

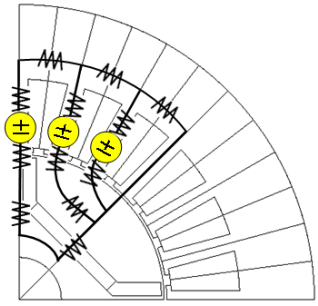


Fig. 1. Magnetic circuit of a motor

There are also software based on the magnetic circuit method. Results can be obtained instantly because an analysis can be performed using very few calculation resources.

Therefore, the magnetic circuit method was widely used in the design process before FEA become a standard tool (before FEA).

Then why has analysis using FEA become necessary and widely adopted in the development process?

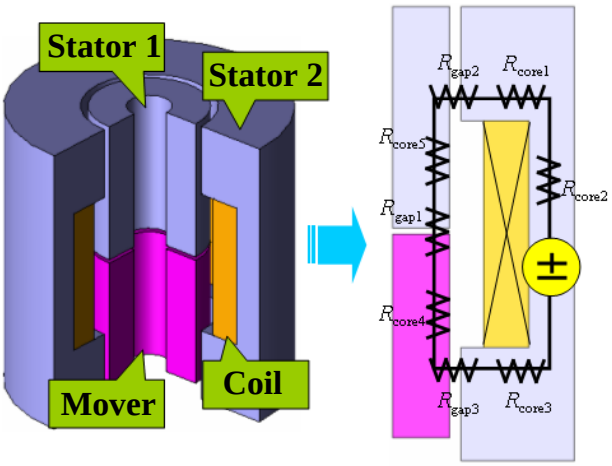


Fig. 2. Model of a solenoid valve using the magnetic circuit method

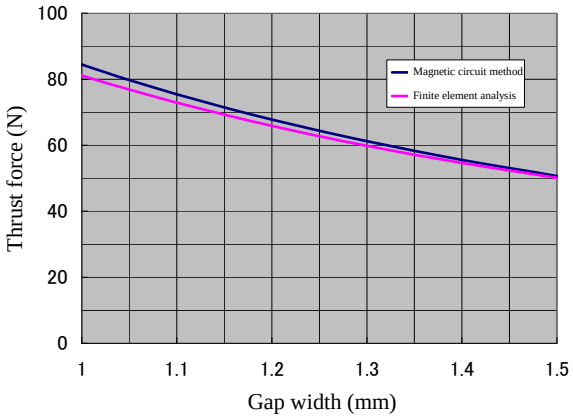


Fig. 3. Attractive force characteristics obtained using the magnetic circuit method in Fig. 2

● Why is FEA being widely adopted?

The magnetic circuit method is a convenient method that can obtain results simply and easily, but a *more authentic magnetic circuit* is required to obtain more accurate results. The primary magnetic pathways the magnetic flux flows need to be predicted and the magnetic resistance of the magnetic circuit needs to be evaluate in advance to define the magnetic circuit. This requires the intuition and experience of designers.

The magnetic circuit is also strongly dependent on the geometry and material properties. The magnetic circuit that needs to be taken into account becomes complex as the geometry becomes complicated. A point sequence of each operating point for the physical values and magnetic resistance also becomes necessary to grasp the nonlinear properties of materials.

The characteristics of the attractive force indicated in Fig. 3 for a wider operating region are indicated in Fig. 4. The error in the magnetic properties is expressed as the error of attractive force because the magnetic saturation is more severe as the gap between the mover and stator becomes thinner (linear properties are assumed in the magnetic circuit method). The geometrical dependency of the attractive force is more prominent as the gap becomes thinner because the magnetic resistance varies largely with the geometry. This means the application of the magnetic circuit method becomes more difficult with the complexity of the geometry for an analysis target that is dependent on nonlinear characteristics.

The geometry often needs to be determined while comprehensively investigating the magnetic saturation and loss distribution of the primary magnetic circuit to achieve the maximum performance of machines, such as motors, during the design process. However, the magnetic circuit method cannot account for distributions such as the magnetic flux density distribution and loss density of a machine by simply replacing and calculating an equivalent circuit for an analysis target.

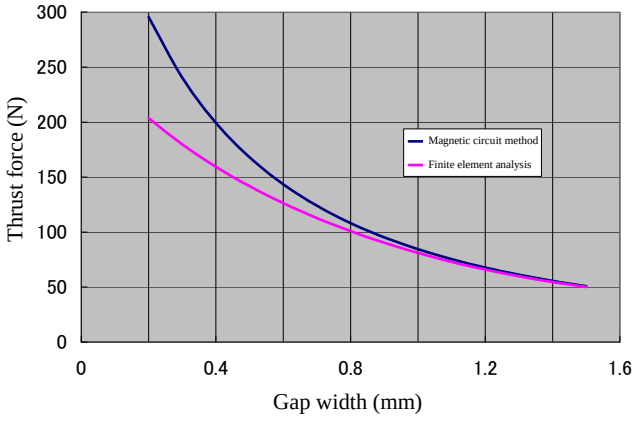


Fig. 4. Attractive force characteristics when expanding the operating range of Fig. 3

FEA is suitable for these kinds of evaluations. The magnetic flux density distribution inside a motor can be comprehensively evaluated using FEA as indicated in Fig. 5. In addition, physical phenomena reflected in geometry, such as the torque ripple, can be examined in detail easily.

FEA performs analyses by modeling the geometry as closely as possible to the actual machine and setting accurate values for the material properties without relying on the intuition and experience of the designer. Therefore, highly accurate results can be obtained by anyone even if they are not an expert in design by following the correct modeling procedures.

FEA can even examine the magnetic saturation and eddy current distribution inside of machines that cannot be directly evaluated using measurements. More information can be acquired using FEA than can even be obtained through experimentation.

The rapidly increasing performance of computation solvers and the technical advancements of analysis methods in recent years are drastically expanding the prevalence of FEA. This has resulted in the rapid application of FEA in the development process.

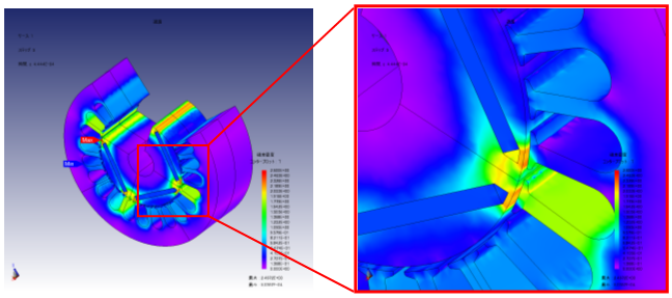


Fig. 5. Magnetic flux density distribution inside a motor

This issue has provided a broad overview for the prevalence and background of FEA in the design process. The next issue will describe the technical background that has made comprehensive and highly accurate analysis possible using FEA.

Utilizing Support

Technical Support Information and One Point Support

The JMAG software is not all that is provided by the JSOL Corporation. We aim to offer simulations that can be used to the fullest potential.

The effectiveness of simulations increases the deeper the user understands how to use the software, how to evaluate the results, and how to apply the simulations for designs. Therefore, we offer the highest level of support services. Our specialized support engineers have the training required to work side by side with users to reach their goal.

A wealth of tutorials and application examples are available for users to further their knowledge independently. Furthermore, there is also various training and seminars provided for users to further increase their proficiency. The JMAG support services can be used by each user to obtain the most from their simulations.

The following introduces the technical support that is available.

Technical Support

Our specialized support engineers are their to assist users' with simulations from operating the software to understanding and evaluating the results that they obtain.

The technical support is provided by email.

◇ When should I use the technical support?

- Our support engineers provide a broad range of support when you are unsure of the procedure from basic operations to the detailed questions of skilled analysis experts.
- Our support engineers will work with you to find the reason analysis results seem strange.
- Our support engineers will propose basic methods to re-examine simulations when you are unsure of what analysis method to use for a simulation.

Interview with the JMAG Support Team:

Q: What are some of the questions frequently asked by users?
A: The questions that are most often asked are related to the operating procedures of course, but, recently the number of questions related to modeling are increasing.

Q: What kind of support do you try and offer users?
A: We continuously ask ourselves whether or not we are getting to the heart of the questions being asked.
Please don't hesitate to explain the objective of an analysis in addition to the problem that you are encountering.

Q: Is there anything else you would like to add?
A: I hope anyone that is using the software will not hesitate in asking questions about anything they find difficult.
We can offer ways of reproducing the desired physical phenomena by fully utilizing the features built into JMAG.

One Point Support

The following explains how to resolve problems generating 3D mesh for CAD data.

The problem has to be refined if the appropriate message is not displayed. Whether the problem is with an individual part or the relationship between parts can be determined by removing the conditions and reducing the parts. The CAD data can be edited or the mesh generation method/element size can be modified once the problem has been identified to a certain degree.

Please contact the JMAG Support Team with the items you would like to evaluate and the status of the simulation if the problem can still not be resolved.

Please take full advantage of our technical support.

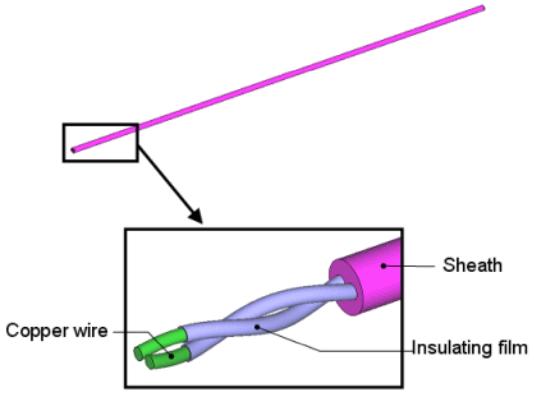
Team Leader Tetsuya Hattori

JMAG Application Catalog

The Application Notes guide users inexperienced in analysis software, or experienced users that want to explore new fields using simulations ,through a smooth analysis process.
Here is an introduction for two of our newest examples. “Analysis of Impedance-Frequency Characteristics of a Cable ”,“Magnetization Analysis Accounting for Eddy Currents ”.

JAC70 Analysis of Impedance-Frequency Characteristics of a Cable

Twisted pair cables are insusceptible to external noise and emit less noise, so they are used for such as speaker cables and power wires which require strict noise reduction. When current frequency in the cable increases, the current flows non-uniformly in the copper wire due to skin effect and proximity effect, resulting in the increase of resistance and the reduction of inductance. Losses are proportional to resistance, and the change in inductance distorts the signal. Therefore, it is important to investigate both resistance and inductance at different frequencies before designing the cable. This note presents the use of magnetic field analysis to obtain resistance and inductance in a cable at different frequencies.



Current Density Distribution

Figure 1 shows the current density distribution in the copper wire. At 10 kHz frequency, current distribution is slightly non-uniform due to proximity effect, and at 100 kHz frequency, current distribution is extremely non-uniform due to skin effect and proximity effect. This non-uniform current distribution affects resistance and inductance.

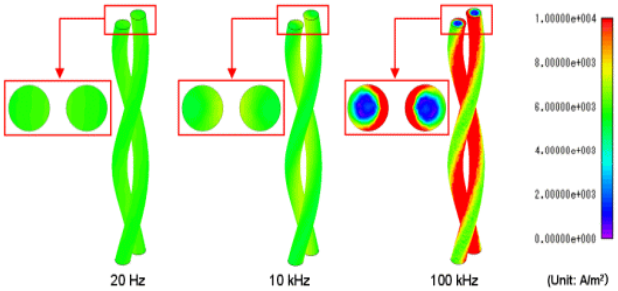


Figure 1 Current Density Distribution in the Copper Wire

Resistance / Inductance

Figure 2 shows the resistance in the copper wire at different frequencies. Figure 3 shows the inductance in the copper wire at different frequencies. Both resistance and inductance start to change at around 10 kHz due to proximity effect, and as the frequency increases, they change sharply due to skin effect. To reduce the proximity effect and the skin effect, the cale needs to be designed to have a structure in which current passes through a conductor uniformly within the usable frequency band.

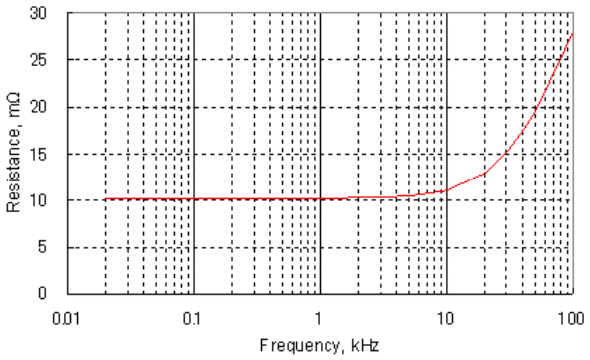


Figure 2 Resistance versus Frequency

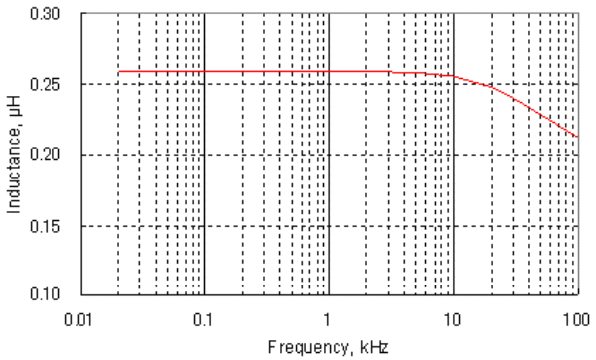
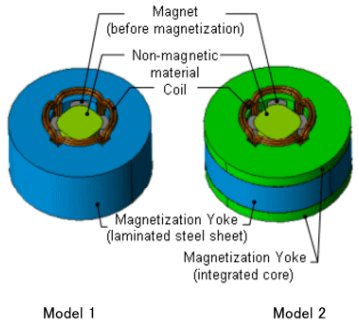


Figure 3 Inductance versus Frequency

JMAG Application Catalog

JAC126 Magnetization Analysis Accounting for Eddy Currents

The orientation of magnets largely affects the characteristics of devices that use permanent magnets. The most desirable magnetization may not be obtained due to eddy currents in the magnetization yoke. Therefore, it is advantageous to investigate these affects in advance. The characteristics of the device can be analyzed by using the magnetization of the magnet based on the magnetization field that is calculated in JMAG.
This note presents the use of a magnetic field analysis to compare the differences in the magnetization distribution of magnets and the surface magnetic flux density of a magnetization yoke that is entirely composed of laminated steel sheet and a magnetization sheet that that does not use laminated steel sheet at each end.



Magnetization Distribution of the Magnets

The magnetization distribution of Magnet A that is magnetized using the device entirely made of laminated steel sheet and Magnet B that is magnetized using the device that does not use laminated steel sheet at each end are indicated in Fig. 1. A 1/4 model emphasizing the magnetization distribution is indicated in Fig. 2. The magnetization distribution is uniform in magnet A whereas the magnetization distribution varies at the top, bottom, and center of magnet B, as indicated in Fig. 1. Furthermore, when magnet A and B are compared, magnet B has a weaker magnetization at the ends of the magnet with stronger magnetization focused in the center, as indicated in Fig. 2.

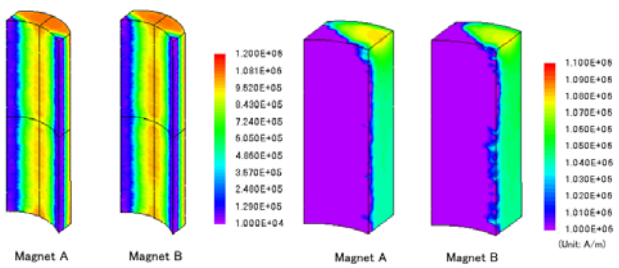


Fig.1.Magnetization distribution of the Magnets

Fig.2.Magnetization distribution of the Magnets(1/4model)

Surface Magnet Flux Density Distribution of the Magnets

The surface magnetic flux density distribution of magnet A magnetized by the device entirely composed of laminated steel sheet and magnet B magnetized by the device that does not use laminated steel sheet at each end is indicated in Fig. 3 through Fig. 5. The position the magnetic flux density is measured is indicated in Fig. 6.

The magnet flux density of magnet B is universally smaller than magnet A as indicated in Fig. 3. The magnet is not sufficiently magnetized because of the eddy currents flowing in the integrated core. The magnetic flux density distribution is almost the same in Fig. 4 and Fig. 5. The eddy currents to not affect the parts of Magnet B at z=9.0 and z=0.0 because this area of the magnetization device uses laminated steel sheet.

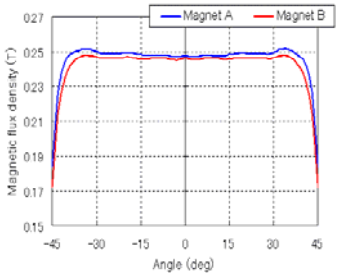


Fig.3.Surface magnetic flux density distribution of the magnet (z=18.0)

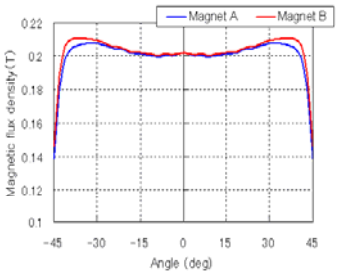


Fig.4.Surface magnetic flux density distribution of the magnet (z=9.0)

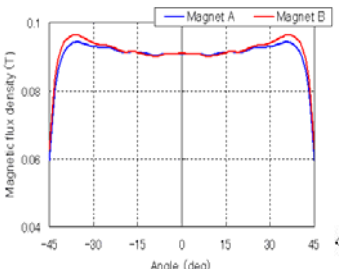


Fig.4.Surface magnetic flux density distribution of the magnet (z=0.0)

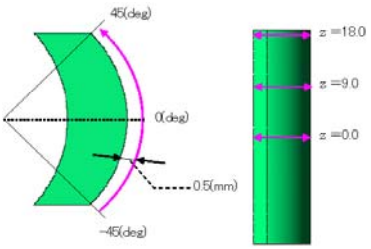


Fig.6.Position of the magnet that the surface magnetic flux density distribution is measured

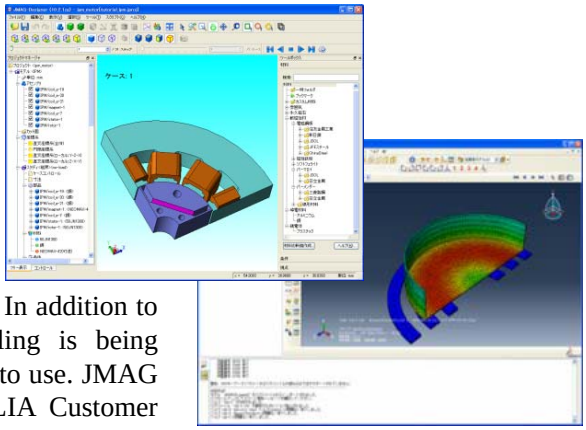
The Application Catalog includes over 120 analysis examples on the JMAG website. Don't hesitate to take a look through the Application Catalog.
http://www.jmag-international.com/catalog/

Event Information

Upcoming Events

2011 SIMULIA Customer Conference (SCC)

Date: Monday, May 16th to Thursday, May 19 2011
Venue: Hotel Fira Palace (Barcelona, Spain)
URL: http://www.simulia.com/bnr1-scc11/



Induction heating analysis using JMAG-ABAQUS

A direct JMAG-ABAQUS link has been released as of December 2010. In addition to the one-way coupling that is currently available, interactive coupling is being developed to provide an even more comprehensive analysis that is easy to use. JMAG will be presented and exhibited for the first time at the 2011 SIMULIA Customer Conference. JMAG's development will continue to aim to be even more versatile based on the feedback we receive from ABAQUS users. Please don't hesitate to join us at the SCC if you are in or around Barcelona.

Coil Winding Expo Berlin 2011

Date: Tuesday, May 24 to Thursday, May 26, 2011
Venue: Messe Berlin (Berlin, Germany)
JMAG Stand: Stand 1406
URL: http://www.jmag-international.com/event/2011/cw2011.html (JSOL)
http://www.coilwindingexpo.com/BERLIN/berlin_home.htm (Official)

Coil Winding Expo Berlin 2010

JMAG will be on display once again at the Coil Winding, Insulation & Electrical Manufacturing Exhibition held in Germany. The following presentations related to JMAG will also be presented at the Inductica Conference, which runs concurrently with the CWIEME, in addition to the presentations hosted at the JMAG booth that have been very highly praised.

JMAG: Simulation Technology for electromechanical Design

Presenter: Mr. Yves Thioliere, Powersys France
Wednesday, May 25 10:30 to 10:50 at the Inductica Conference

The highly advanced electrical machines of today require limit state design. Capturing and evaluating the inner workings of electrical machines is vital to satisfy the stricter demands of designs. An evaluation and analysis environment driven by "JMAG" can step up to these demands.

Modular Stator Core Solutions for PMSM a FEM Based Comparative Analysis

Presenter: Dr. Dorin ILES, ILES-Engineering, Germany
Thursday, May 26 12:00 to 12:30 at the Inductica Conference

JMAG Users Conference in Germany

Host: POWERSYS
Date: Tuesday, June 28, 2011
Venue: STEIGENBERGER AIRPORT HOTEL (Frankfurt, Germany)
URL : http://www.powersys-solutions.com/usersconference_jmag_2011.php

The JMAG Users Conference is reaching out internationally to be held in Germany, Taiwan, and Tokyo this year. A wide-range of user cases for applications of JMAG in Europe will be introduced via lectures and posters including a presentation by VALEO Electrical Systems about how they have utilized JMAG. JMAG-Designer Version 10.5, which is scheduled to be released in July, will be unmasked for the first time at the JMAG Users Conference in Germany. We can't wait to see you there!

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