Utilizing JMAG Designer for 3D Magnetic Field Analysis Models

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Abstract :
In recent years, the technical development of brushless motors for a higher output density and miniaturization are increasing with the demand for energy efficient motors as the cost of raw materials rises around the world.
This presentation examines the magnetic pathways of motors three dimensionally to achieve a brushless motor that has a higher output density focusing on analysis examples that utilize the CAD link features provided in JMAG-Designer.

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Utilizing JMAG-Designer for 3D Magnetic Field Analysis ModelsJMAG-Designer

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Motor Development Center Corporate Engineering Division
Yuichi Yoshikawa

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Features of JMAG-Designer

JMAG-Designer
⇒ Succeeding platform combining [JMAG-Studio] + [Usability]

◆Self Learning System
◆Geometry Editing Features (CAD Like Geometry Editing)
◆Enhanced **CAD** Link Features
（Link to SolidWorks、CATIA V5、Pro/ENGINEER、and NX）
◆Simplified Material and Condition Settings (Treeview Format)
◆Vast Management Features
(Simultaneously manage multiple models and studies as a single project)
... and other features that are easy to use.

Maintains material and condition settings even when geometry is edited in CAD software by using CAD link features.

Advantageous for motor design that has complex geometry such as 3D core structures.

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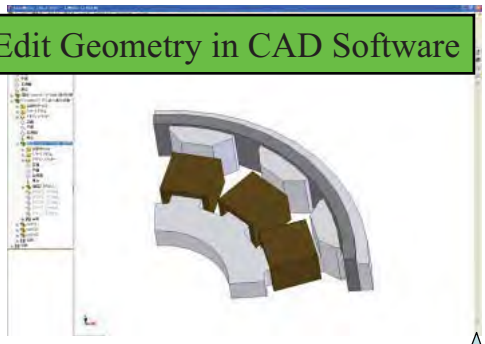
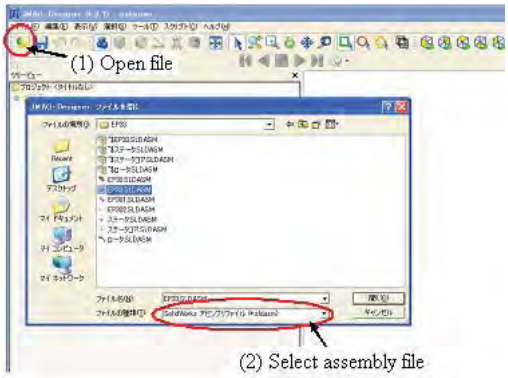
CAD Link Features

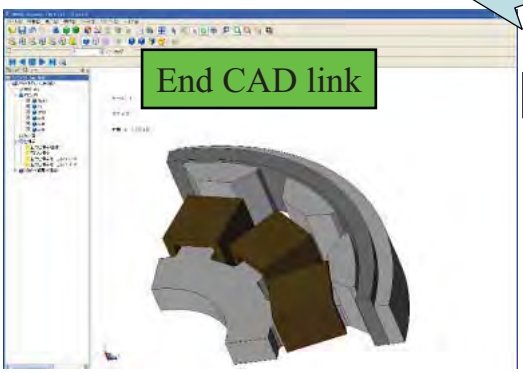
◆Analysis Flow (Editing Geometry)

Edit Geometry in CAD Software

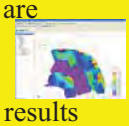




End CAD link



Because the material and conditions are maintained from previous settings:
(1) Generate mesh
(2) Run analysis --> Obtain analysis results



For JMAG-Studio

1 hour to edit the geometry and run the analysis

For JMAG-Designer

5 minutes to edit geometry and run the analysis

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Contents

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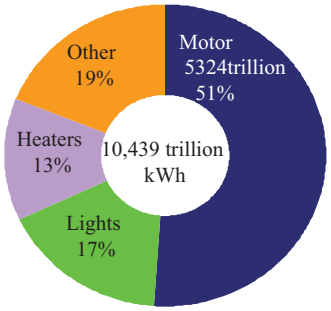
Background (Motor Environment)

■ Power Consumption in Japan and Motors

2006 Domestic power consumption

Approximately 1／2 of the electric power is consumed by motors



* Power consumption: Based on "FY 2008 Annual Energy Report" Agency of Natural Resources and Energy

*The power generated is at 100% capacity, rated output ×24 hours ×365 days.

*Oil power power plants CO2emissions are calculated as 742g/kWh.

Improved motor efficiency of 1%

53 trillion kWh/year reduction in power consumption

Corresponds to power generated by 1 mid-size nuclear power plant

Converting to CO_2 emissions of thermal power plants
Reduction in 3.93 milliontonsof CO_2 emissions

* based on internal research

More highly efficient motors are a must

■ Rising cost of raw materials

Resource saving design of motors is a must ➡ Investigate improved power density of motors

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Higher Output Motors

◆For higher output density (resource saving design)

$$\text{Output density} = \frac{\text{Output}}{\text{Motor dimensions}}$$

The smaller the motor dimensions, the smaller the material used.
Reduction in high risk materials

Higher torque

Benefits
- Possibilities for Direct Drives
- Noise reduction

Demerits
- Increased motor size

Increased costs

Higher speed

Benefits
- Miniaturized motors

Demerits
- More vibration/noise
- Requires flux-weakening control
- Maintaining rotor strength

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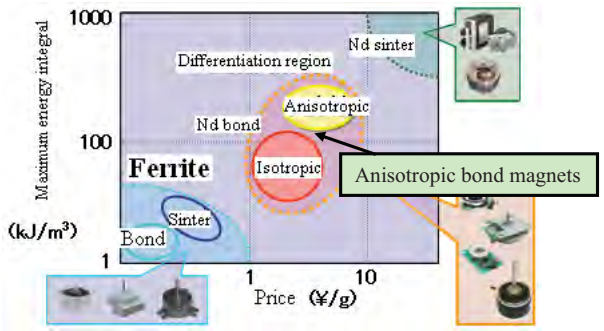
Higher motor torque

The output of brushless DC motors is determined by the magnetic energy in the air gap.

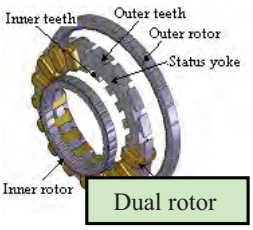
(1) Using stronger magnets



A balanced design between magnet cost and performance is necessary

(2) Increasing the gap area

2D structure



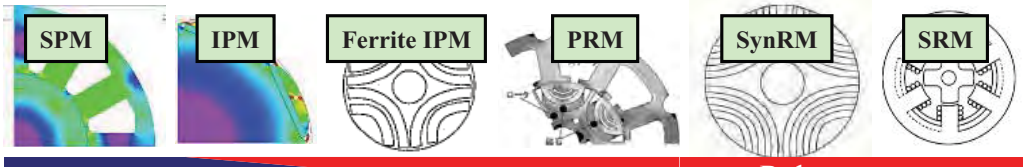
Dual rotor

3D structure

Dust cores, etc. (3D cores)

Enlarge the gap area effectively utilizing the space in 2D/3D structures ⇒ increased magnetic flux

(3) Utilize principles producing torque other than magnets (Expanding reluctance torque)



Magnet torque — Reluctance torque

Higher output and elimination of rare earth materials by utilizing reluctance torque

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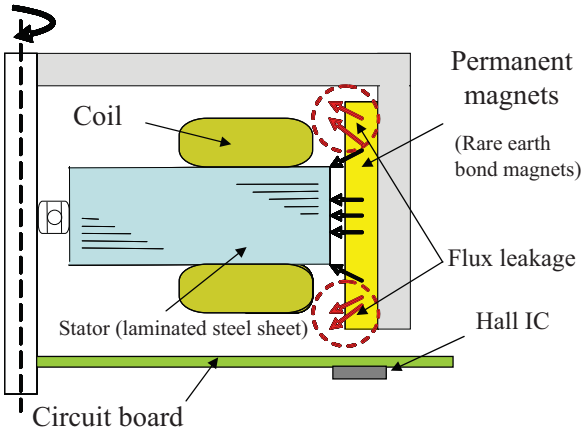
3D core structure

《Standard outer rotor》

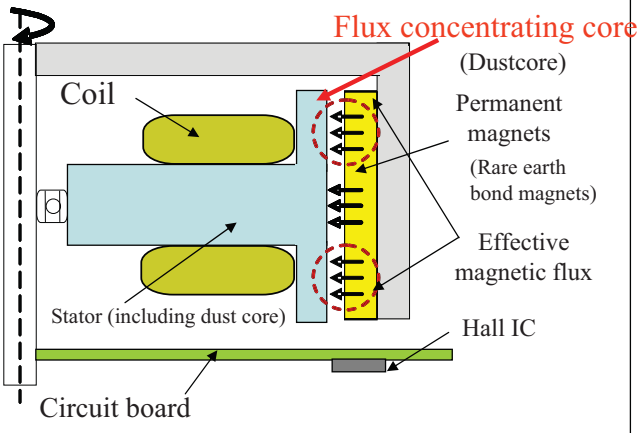


Magnets overhung for position sensing using Hall IC.

◆Flux leakage produced at areas the magnets overhang

Fewer magnets used ⇒ Lower output density

《3D core structured outer rotor》



Structure the stator with a dust core to achieve a 3D core (flux concentrating core) structure

◆Effectively utilize flux leakage in overhanging magnets

Many mangets used ⇒ Improved output density

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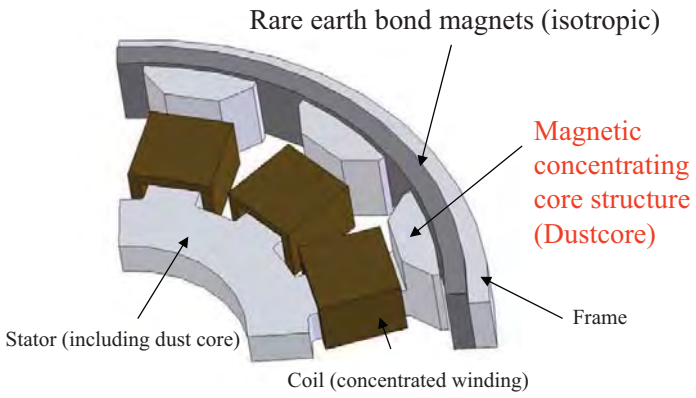
Features of a 3D Structured Outer Rotor

[Motor Structure]



[Motor parameters]

Motor type	Outer rotor SPM
Number of poles and slots	16-poles 12-slots
Outer Diameter	Φ70
Lamination	15㎜
Magnet quality	Rare earth bond (isotropic)
Output	100W (2D core) ⇒ 125W (3D core)

[Features]

◆1.2 to 1.3 times the output density can be achieved by effectively utilizing flux leakage
(further miniaturization for the same output)
◆Cogging torque worsens by 3-dimensional variations in magnetic flux (hard to prevent using only motor geometry)
⇒ The magnetic flux density in the gap differs with a laminated core and magnetic concentrating core for the stator.]

Examine cogging torque reduction using a JMAG-Designer magnetization analysis

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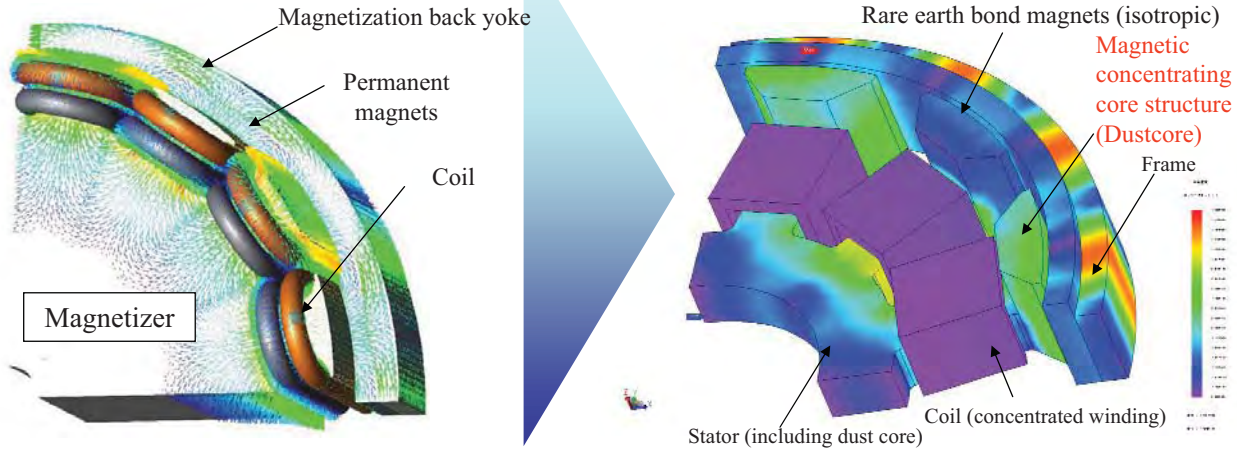
Magnetization analysis of a 3D core (1)

3D magnetization analysis

3D magnetic field analysis



(1) Utilize the magnetic flux orientation obtained in the 3D magnetization analysis for the magnetic field analysis.
(2) Calculate the motor characteristics such as cogging torque and induced voltage using a 3D magnetic field analysis.
(3) Repeat 1 and 2 changing the geometry of the magnetizer and magnetization conditions.

3D magnetization analysis using JMAG-Designer

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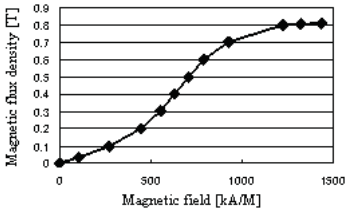
Magnetization analysis of a 3D core (2)

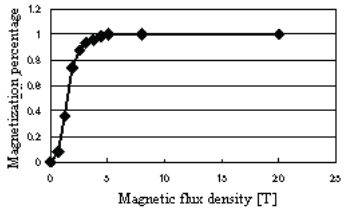
[Analysis conditions]

Using the JMAG-Designer magnetization analysis feature
- Number of elements: 180 thousand to 220 thousand
- Using incomplete magnetization

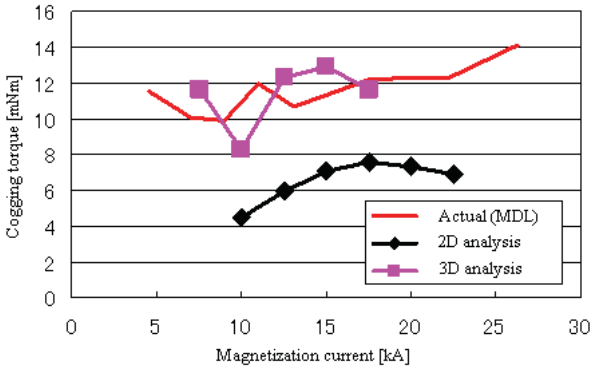
<Initial curve>



<Magnetization>

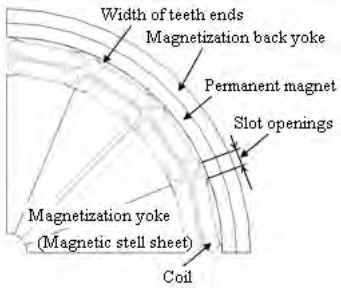


[Consistency of analysis]



◆Limitations of 2D analyses
◆Consistency of 3D analyses

[Design parameters of magnetizer]



Design parameters
- Thickness of magnetization back yoke
- Slot openings
- Width of teeth ends
- Position of Coil
- Number of turns
- Wire diameter... etc.

◆Optimize cogging torque and induced voltage by changing design parameters.

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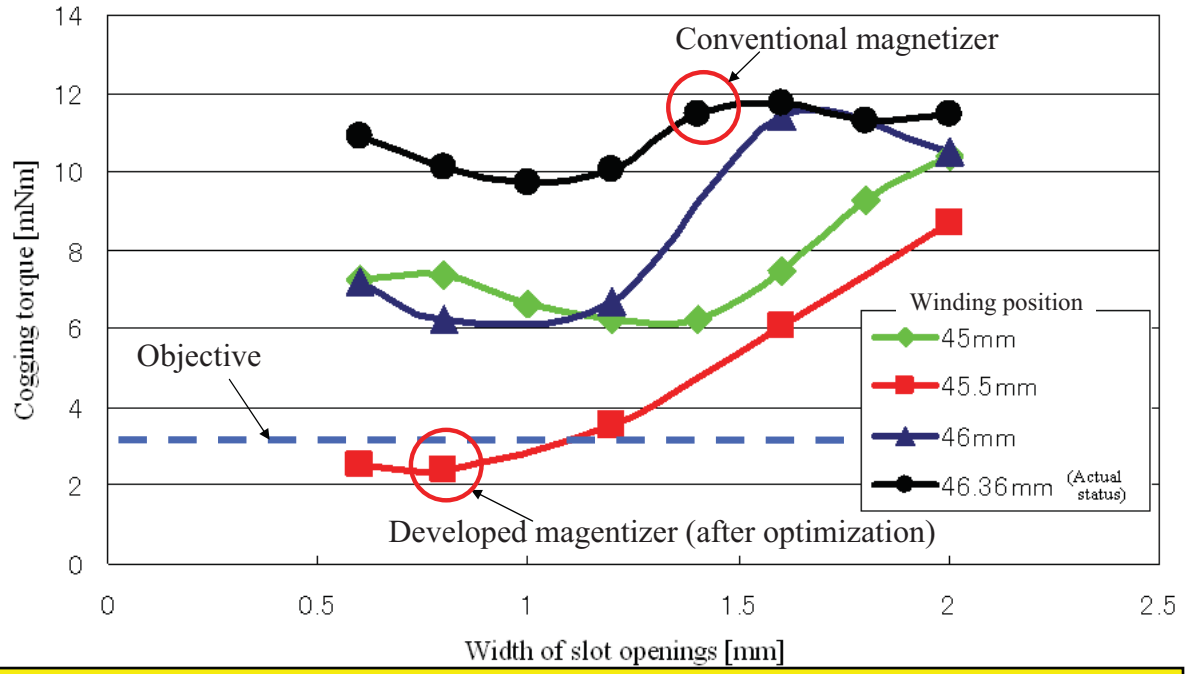
Optimization Design of Magnetizer (Analysis)

《Optimization Design of Magnetizer》 Relationship of slot openings and winding position



Achieve desired cogging torque by optimizing the width of the slot openings and position of windings

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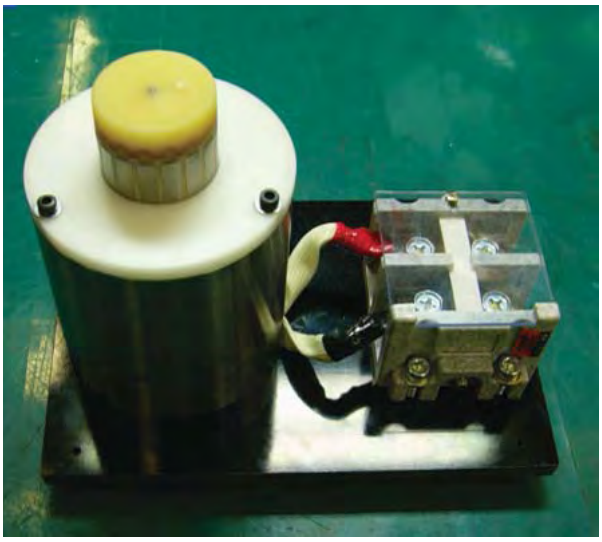
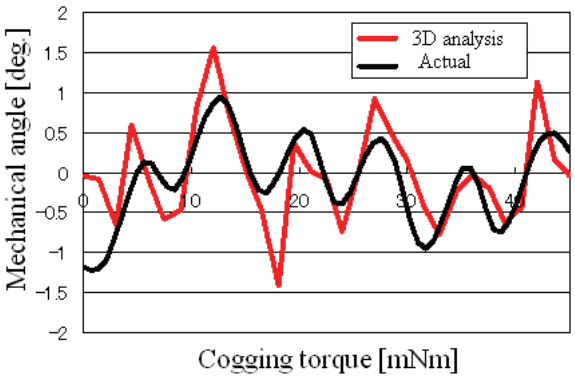
Examine the prototype

《Examination using the prototype of the magnetizer》

Build an actual prototype of the magnetizer and confirm the reduction in cogging torque.





	Cogging Torque	Induced voltage
Objective	3**mNm**	100
Conventional magnetizer	10**mNm**	95
Developed magnetizer	3**mNm**	100

Confirm the actual reduction of cogging torque

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Conclusion

◆、1.2 to 1.3times the output density was obtained by examining the higher output density for outer rotor type SPM motors using a magnetic concentrating core (dust core).

◆ The cogging torque was reduced to one third the conventional technology by optimizing the design of the magnetizer using the JMAG-Designer 3D magnetization analysis.

The time required to specify analysis condition settings was reduced to less than 1/10 by utilizing JMAG-Designer

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