

#### E-MOTOR CFD ANALYSIS: IKERMAQ MOTOR

FLUX-ACUSOLVE COUPLING APPLICATION (VIA SIMLAB)

June 2022, Altair Engineering Inc.

#### **TUTORIAL OUTLINE**

### I. Introduction

## II. 2D Electromagnetic Analysis (Flux)

• II.1: Loss computation

III. 3D CFD Analysis (SimLab / AcuSolve)

- III.1: eMotor CFD meshing
- III.2: CFD solution setup

**IV.** Conclusion



### INTRODUCTION



### **INTRODUCTION**

#### Application Case: IkerMAQ Motor

- About the machine: IkerMAQ<sup>1</sup>
  - Permanent Magnet Synchronous Machine
  - Performance study
    - Transient magnetic analysis
    - NVH analysis
      - Vibration analysis
      - Acoustic analysis
    - Thermal analysis

4



Parameter	IkerMAQ
Power	75 kW
Speed	1080 rpm
Torque	700 Nm
EMF (phase)	$293 V_{rms}$
Current (phase)	87 A <sub>rms</sub>
External stator radius	0.188 m
Effective length	0.31 m
Pole pairs number	5
Slots number	45
Internal stator radius	0.139 m
Airgap	2.5 mm
5.1	



### **INTRODUCTION**

#### Application Case: IkerMAQ Motor

- CFD model illustration in SimLab •
  - Air cooling system ٠



### **INTRODUCTION**

#### E-Motors CFD Analysis with SimLab

• Analysis workflow (Flux-AcuSolve one way coupling application)





#### 2D ELECTROMAGNETIC ANALYSIS (FLUX)



### LOSS COMPUTATION



#### Loss Computation

- Loss distribution inside an eMotor
  - Generally, it can be divided into the following three cases







Loss Computation: Total Value Method

- Loss distribution inside an eMotor
  - The losses insides an eMotor will be defined as **Heat Sources** in SimLab for AcuSolve.



 As the temperature distribution in coil regions (both straight parts and the end-windings) and magnet regions is quite homogeneous, the Heat Source of the coil and magnet bodies can be defined using the total loss value.





Loss Computation: Nodal Mapping Method

- Loss distribution inside an eMotor
  - The losses insides an eMotor will be defined as **Heat Sources** in SimLab for AcuSolve.



• As iron loss distributions in the stator region and the rotor region are not homogeneous, the Heat Source of the stator / rotor bodies is better to be defined using the **nodal mapping method.** 





#### Loss Computation: Flux Initiation

- Run the predefined 2D electromagnetic analysis (in motor mode)
  - Open the project "IkerMAQ\_MotorMode.FLU" in Flux

Altair Flux <sup>™</sup>	2D	Skew	3D	PEEC		Open Altair FluxMotor™	🛆 ALTAIR
New project	How to proceed? 1) Select the working module (2D, 2) Select the working directory 3) Select the file revealer to the ra	Skew, 3D or PEEC)					
Open project	4) Click on "Open the selected proj	ect" (ar double-click directly on the se	lected project)				
Open example	Working directory E:\SimLab\CFD\D	kerMAQ_CFD10_Release \eMotorOPD_	RerMAQ\1_Flux_ini				
	Directory selector	Name		074	Current projects	Tune	
Python scripts	OptStruct	2_2021 Gay14/	Q_MotorMode.FLU		6.968 MB	2022/06/29 11:58 AM	Flux 2D project
Batch solve	Personal     ProjectPiles     QA_Flux     SmLab						
	Image: Section         Code           Image: Section         Code           Image: Section         Section           Image: Section         Section <th>Q, 20 Jitest ModeSalved FLU Q, 20 Jitest ModeSalved FLU Q, 20 Jitest ModeSalved FLU Q, 20 Jistor ModeSalved FLU</th> <th>Ste</th> <th>Recent projects Date 1943-855 MB 1943-855 MB 1943-855 MB 54-835 MB 54-835 MB</th> <th>7,pe 2022/04/28 5-03 FM 2022/04/28 5-03 FM 2022/04/20 11:01 344</th> <th>Flux 3D project Flux 3D project Flux 3D project Flux 3D project</th>		Q, 20 Jitest ModeSalved FLU Q, 20 Jitest ModeSalved FLU Q, 20 Jitest ModeSalved FLU Q, 20 Jistor ModeSalved FLU	Ste	Recent projects Date 1943-855 MB 1943-855 MB 1943-855 MB 54-835 MB 54-835 MB	7,pe 2022/04/28 5-03 FM 2022/04/28 5-03 FM 2022/04/20 11:01 344	Flux 3D project Flux 3D project Flux 3D project Flux 3D project
210	Electric     Structure     Structure	Appl y utator/CFD State 2 Com unProject Ent	ETMAQ_MOTOTMODE.FLU			And the second s	
Open the selected project	🔁 Fie Man	lager					
Options Material	ion Material Manager	e-Machine Toolbox	Manager 6	depth		Manager Manager	r Command Line
Physical memory	15.40 GB/63.76 GB		Allocable memory	16.40 GB/64.76 G	ið Disk space	1:57 TB(1:62 TB	



#### Loss Computation: Flux Initiation

- Run the predefined 2D electromagnetic analysis (in motor mode)
  - [Solving] [Solve] (as a new project "IkerMAQ\_MotorMode\_Solved.FLU")



#### LOSS COMPUTATION: TOTAL VALUE



### **2D ELECTROMAGNETIC ANALYSIS**

#### Loss Computation: Total Value Method Data exchange Support Graphic Curve Computation Advanced Display View Help Application . 💌 0 🕨 😫 🌌 🛷 🎊 🖄 炎 阖 5 M Ta , On point K Compute On physical entity Data Tree 隆 Edit Ctrl-E General data omputation of iron losses Delete Supprimer Winding Joule losses + Geometry [2] Computation of inductance matrix • + Mesh Evaluation of the demagnetization + D Physics Parameter/Quantity GP Open mechanical analysis context [Computation] – [On physical entity] – [Compute] + 🙆 Solver ٠ + Dost processing 2.288 В + Cools 2.135 Extensions 00' The value computed by the "Computation on circuit" Ledit Compute on physic entity[ComputePhysic] $\times$ tool is based on the full model Computation on circuit General \ Computation context \ Storage name \* Winding Loss 1 Type of electrical component Computed formulas Coil conductor -Region Circuit Mechanical set Formula PjouleCC(PHA) f() PHA Voltage [V] Add f() f() PjouleCC(PHA) PjouleCC(PHB) PHB Current [A] f() PiouleCC(PHC) f() PjouleCC(PHB) PHC Power - Active [W] f() PiouleCC(PHC) PiouleCC(PHA)+PiouleCC(PHB)+PiouleCC(PHC) f() Add all TESTING COIL CONDUCTOR Flux IWb1 f() f() Joule losses [W] Clear Delete all Results of computation Label Value Circuit - Coil conductor / Joul... 338, 172219311186 W Circuit - Coil conductor / Joul... 410.439580469428 W Circuit - Coil conductor / Joul... 1493.72726417655 W PjouleCC(PHA) +PjouleCC(PH... 2242.33906395717 Ok Cancel Compute Store Close

Project

Solving

Formula to compute total Joule losses on winding area: *PjouleCC(PHA)+PjouleCC(PHB)+PjouleCC(PHC)* 

#### Loss Computation: Total Value Method

- Winding Joule losses
  - Straight part: 2242.34 W

😓 Edit Compute on physic entity[ComputePhysic]				
General \ Computation context \				
Storage name *				
Winding_Loss_1				
Computed formulas				
Region	Circuit Mechanical set			
PjouleCC(PHA)	f()			
PjouleCC(PHB)	fO			
PjouleCC(PHC)	fO			
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Results of computation				
Label	Value 👔			
Circuit - Coil conductor / Joul	338.172219311186 W 🗸			
Circuit - Coil conductor / Joul	410.439580469428 W 🗸			
Circuit - Coil conductor / Joul	1493.72726417655 W			
PjouleCC(PHA)+PjouleCC(PH 2242.33906395717				
Compute Store	Close			

Overview	Current					
Winding a	and Magnet charact	eristics				
Winding						
Winding con	nection	Wye	Winding resistance factor	1.0		
Winding tem	perature (°C)	20.0				
Phase resista	ance (Ω)	5.365 E-2	Line-Line resistance (Ω)	1.073 E-1	End winding resistance (Ω)	2.916 E-2
In slot windi	ng (°C)	20.0	C.S. end winding (°C)	20.0	O.C.S. end winding (°C)	20.0
Winding stra	aight part resistance (Ω)	2.45 E-2	C.S. end winding resistance (Ω)	1.737 E-2	O.C.S. end winding resistance (Ω)	1.179 E-2
Magnets						
Magnet nam	e	Magnet_1	Material name	USER.N48SH-I	Material reference temp. Tref (°C)	20.0
Remanent in	duction at Tref (T)	1.27	Intrinsic coercive field at Tref (A/m)	1.512 E6	Relative permeability at Tref	1.05
Magnet tem	perature Tmag (°C)	20.0				
Remanent in	duction at Tmag (T)	1.27	Intrinsic coercive field at Tmag (A/m)	1.512 E6	Relative permeability at Tmag	1.05

	R / Ohms	Loss (full model) / W	Loss (periodic model) / W
Straight part	0.0245	2242.34	448.47
C.S. end windings	0.0173	1583.37	316.67
O.C.S. end windings	0.0117	1070.83	214.17



#### Loss Computation: Total Value Method

- Magnet losses
  - [Computation] [On physical entity] [Compute]



Edit Compute on physic entity[ComputePhysic]		The value computed by the " <b>Computation on circuit</b> "
General \ Computation context \	😼 Computation on circuit	tool is based on the <b>full</b> model
Storage name * Magnet_Losses	Type of electrical component	
Computed formulas	Solid conductor 2 terminals	
Region Circuit Mechanical set		Ecrowita
PjouleSC(SOLIDCONDUCTOR2TERMINALS_1) <u>f()</u> PiouleSC(SOLIDCONDUCTOR2TERMINALS_2) f()	SOLIDCONDUCTOR 2TERMINALS_1 Voltage [V] SOLIDCONDUCTOR 2TERMINALS_2 Current [A]	Add
PjouleSC(SOLIDCONDUCTOR2TERMINALS_3)	SOLIDCONDUCTORZTERMINALS_3 Power - Active [W]	Add all
	Joure rosses [w]	
		Delete
Clear		
Results of computation	Total Joule losses in the magnet reg	gion:
Circuit - Solid conductor / Jou 0.994968840575822 W	Full model: 0.995 W + 0.669 W + 0.	036 W = <b>1.7</b> W
Circuit - Solid conductor / Jou 0.668818037980717 W Circuit - Solid conductor / Jou 0.036178648233231 W	Periodic model (1/5 of the full mode	$1) \cdot 1 = 7 \cdot 10 / 5 - 0 3 / 10 / 10 / 10 / 10 / 10 / 10 / 10 $
		$1.1.7 \sqrt{7} = 0.34 \sqrt{7}$
	Ok Ca	ncel

Project Application Solving Data exchange Support Graphic Curve Computation Advanced View Help

### **2D ELECTROMAGNETIC ANALYSIS**

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Loss Computation: Iotal Value Me	thod	2      2      3
<ul> <li>Iron losses: stator</li> <li>[Computation] – [Computation]</li> </ul>	Data Tree General data General data Gener	Computation of iron losses  C Computation of iron losses  C C Computation of iron losses  C C C C C C C C C C C C C C C C C
Iron losses computation       X         Computation type       On regions         Definition Results       Image: Computation Results         STATOR       Image: Computation Results         Time Interval       Image: Computation Results         X choice       Parameter name       Current value         X choice       Parameter name       Current value         Y       6.0       78.0         Part of cycle described by the time interval       Image: Computer Name       Image: Computer Name	Iron losses computation     X Computation type On regions     Definition Results Result curve name* CURVE_LOSS_REGION_STATOR Result name* LOSSES_IN_REGION_STATOR Spatial quantity name for the average loss density* DVOL_LOSS_MEAN_STATOR Spatial quantity name for energy density* DVOL_ENERGY_LOSS_STATOR	Image: Contract of the contract
18	Average iron losse Periodic model (1/3 Full model: 328.87	es in the <b>stator</b> region: /5 of the full model): <b>326.91</b> W 7 W * 5 = <b>1634.55</b> W OK APPIY Cancel Detail >> • • • • • • • • • • • • • • • • • •

Project Application Solving Data exchange Support Graphic Curve Computation Advanced View Help

### **2D ELECTROMAGNETIC ANALYSIS**

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Loss Computation: Total Value Me	ethod 📃 🕑 😹 🖉 🖉	👱 / 🔁 🗽 箔 🔊	Dn point     Dn point     Dn physical entity	💵 📓 🎽 💥 🍕 🎘 🏭 🔭 🏭 🔭
<ul> <li>Iron losses: rotor</li> <li>[Computation] – [Computation]</li> </ul>	Data Tree Data Tree Concernent data Concernent y Concernent y Conce	The va	Computation of iron losses  C Computation of inductance matrix  C Computation of the demagnetization  F Open mechanical analysis context  C Computed by the "Iron	Computation of iron losses Deprecated versions  R Edit Ctrl-E R Delete Supprimer R TXT export Excel export Coss computation"
Iron losses computation     Computation type	Iron losses computation X Computation type	🔂 Edi 🚺	ool is only based on the <b>p</b>	eriodic model
Offinition Results         Laminated face regions         RUTOR         Time interval         X choice Parameter name         Current value         Limit min         Limit max         Ø ANGPOS_ROTOR         Full cycle	Definition Results Result curve name * CURVE_LOSS_REGION_ROTOR Result name * LOSSES_IN_REGION_ROTOR Spatial quantity name for the average loss density * DVOL_LOSS_MEAN_ROTOR Spatial quantity name for energy density * DVOL_ENERGY_LOSS_ROTOR	LOSSES_IN_REG Comment 06/30/22 16:43:27 Results \ Descri Iron losses LS iron losses LS iron losses Average iron loss 5.05539407426	ION_ROTOR ption  ses (over a period) (W) * 4637	
Model for losses LS predefined sheets Designation (E.U. standard, BS EN 10106) M800_65A	Average iron loss Periodic model (1, Full model: 5.10 V	es in the <b>roto</b> /5 of the full r V * 5 = <b>25.3</b> V	or region: model): <b>5.06</b> W <i>N</i> Apply Cancel De	etair >>
19 OK Cancel @ Picture	Cancel OK Cancel Picture			

#### Loss Computation: Total Value Method

- Loss computation in Flux: total value method
  - Save the project as "IkerMAQ\_GlobalLossValue.FLU"

Project	Application	Solving
Nev	V	Ctrl-N
🕑 Оре	en project	Ctrl-O
🍠 Clos	se	
Rec	ent projects	•
🔡 Sav	e	Ctrl-S
🔡 Sav	e as	
nd Con	nmand file	•
🔶 Mac	ro	•
🕐 Ove	erlay	•
Exp	ort	•
🕑 Prin	ıt	•
- Kate Exit	:	Alt-F4



#### LOSS COMPUTATION: NODAL MAPPING



Loss Computation: Nodal Mapping Method

- Loss computation in Flux: nodal mapping method
  - Need the spatial quantities created in the previous step
    - Continue to work on the project "IkerMAQ\_GlobalLossValue" in Flux





Loss Computation: Nodal Mapping Method

Iron loss export from Flux •

Data relievition Data visualizer Data avviort Dienlav View Heli

- Export the nodal loss values from Flux to AcuSolve ٠
  - [Data exchange] [Open data Import/Export context] •







Data export

Display

Help

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Graphic

Ż 0

### **2D ELECTROMAGNETIC ANALYSIS**

Loss Computation: Nodal Mapping Method

Iron loss export from Flux •

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Create data support: **ROTOR** ٠



Data support

New

Edit

🔠 Delete

Project

Data Tre

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Data collection

Ctrl-E

Supprimer

Data visualizer

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Data export

Display

Help

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### **2D ELECTROMAGNETIC ANALYSIS**

Loss Computation: Nodal Mapping Method

Iron loss export from Flux •

•

Create data support: **STATOR** ٠



Data support

New

Project

Data collection

Data visualizer

Æ

Loss Computation: Nodal Mapping Method

- Iron loss export from Flux
  - Create generic data collection
    - [Data collection] [Generic data collection] [New]

OK

Cancel

	Information on the scenario				
	Scenario : WORKING_POINT State of the scenario :	New Generic data collection			
	<ul> <li>Scenario fully processed</li> </ul>	Name of the data collection *			
	Information on the current computation step	DataCollection_ROTOR			
	ANGPOS_ROTOR : 🖌 78.0	Comment			
	State of the current computation step : Correctly solved				
	Colort the star	Data collection			
	Select the step	Generic data collection			
	Select the created DataSupport	Collection support *			
	Color ale cleated Datacappent	DATASUPPORT_ROTOR			
c	Coloct the dedicated anoticl quantity formula	Formula of the value to collect *			
0	elect the dedicated spatial quantity formula	DVOL_LOSS_MEAN_ROTOR			
		Type of value			
	Select "Average values in elements"	Average values in elements			
		Collection interval			
	Collect the data only for the current step	Collect only for the current step			
	(the last <b>EM</b> solution stop)				
	(the last EIVI solution step)				
1					
	26				



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😓 New Generic data collection 🛛 🕹		
Name of the data collection *		
DATACOLLECTION_STATOR		
Comment		
Data collection		
Generic data collection 👻		
Collection support *		
DATASUPPORT_STATOR		
Formula of the value to collect *		
DVOL_LOSS_MEAN_STATOR f0		
- Type of value		
Average values in elements 🔹 👻		
- Collection interval		
Collect only for the current step		
OK Cancel		



Loss Computation: Nodal Mapping Method

- Iron loss export from Flux •
  - Create data export

Project Data support Data collection Data visualizer	Data export Display View Help
🗶 🕹 🔒 🍠 🖪 💁 🗛 🎋 🖀 🖉 🦺	🐡 Export to OptiStruct 🔹 👔 📳
Data Tree	K Export to HyperView
🕞 General data	🥌 Export to Acusolve 🔹 🔖 🕙 New
+ A Data support	📳 Export to Nastran 🔹 🗶 Edit 🛛 Ctrl-E
Thermal data collection	🛃 Export to a tabulated data file 🔹 🎽 Delete Supprimer
<ul> <li>Derived data collection</li> <li>Data visualizer</li> </ul>	Export a data support

<ul> <li>[Data export] – [</li> </ul>	Export to AcuSolve] – [New]	😪 New Export data to Acusolve	×
		Name *	
	🐁 New Export data to Acusolve 🛛 🗙	Comment	
	Name *		
	DataExport_RotorLosses	Data collection export	
IkerMAQ_CFD_R IkerMAQ_CFD_St	Comment	Export data to Acusolve	-
otorLosses.nas atorLosses.nas		Data type to export	
Solaat "Export data ta AauSalva"	Data collection export	Heat source (static)	-
Select Export data to AcuSolve	Export data to Acusolve 👻	Collection to export on active step *	
	Data type to export	DATACOLLECTION_STATOR	
Select "Heat source (static)"	Heat source (static)		
	Collection to export on active step *		
Select the defined DataCollection	DATACOLLECTION_ROTOR -		
		File name *	
		IkerMAQ_CFD_StatorLosses	💆
		OK Cancel (R)	
Define the export file name	File name *		<u> </u>
27			
	OK Cancel	•	

Loss Computation: Nodal Mapping Method

- Loss distribution inside an eMotor
  - Loss computation in Flux<sup>1</sup>
    - Save the project as "IkerMAQ\_NodalLossMapping.FLU"

Project	Application	Solving	Data exchange	Support	Graphic	Curve	🐁 Choose th	se the new name of the project X
New Oper	n project	Ctrl-N Ctrl-O	2 🕨 🖲	5 📐 箔	<b>\$</b>	5	Save In: 🗀	LossComputationCFD
Rece	nt projects	•				•		
🔡 Save		Ctrl-S						
🔡 Save	as							
🔶 Comr	mand file	•						
📌 Macr	o	•						
🕐 Over	lay	•						
💋 Expo	rt	•					File Name:	: IkerMAQ_NodalLossMapping
🎯 Print		•					Files of <u>Type</u> :	vpe: Flux2D Project directories
🛃 Exit		Alt-F4						Save Cancel



#### 3D CFD ANALYSIS (SIMLAB / ACUSOLVE)



#### **EMOTOR CFD MESHING**



#### eMotor CFD Meshing

• Full motor modeling for thermal analysis







#### eMotor CFD Meshing

- Periodic modeling (axisymmetric model) for CFD analysis
  - With outside air fluid region







#### eMotor CFD Meshing

- Periodic modeling (axisymmetric model) for CFD analysis
  - Open the project "IkerMAQ\_CFD\_Mesh.slb"





### **CFD SOLUTION SETUP**



- Create a **Solution** for CFD analysis
  - [Solutions] [Flow]





#### **CFD Solution Setup**

Create a Solution for CFD analysis



Heat Source

Reference

Frame

Components.

Results Electronics Advanced Inspect Automation Extensions 🕂

Initial Condition

### **3D CFD ANALYSIS**

#### **CFD Solution Setup**

•

- Define Flow Domain: Reference Frame
  - [Analysis] [Reference Frame]



Solutions Sketch Geometry Mesh Analysis

Move

Files

Measure

Home

Material

Material

Coordinate...

Heat Source

Reference

Frame

Components..

Results Electronics Advanced Inspect Automation Extensions 🕂

Initial Condition

### **3D CFD ANALYSIS**

#### **CFD Solution Setup**

Rotor

•

- Define Flow Domain: Reference Frame
  - [Analysis] [Reference Frame]



Files

Measure

Home

Solutions Sketch Geometry Mesh Analysis

Move

Material

Material

Coordinate...



### **3D CFD ANALYSIS**

#### **CFD Solution Setup**

Shaft

•

- Define Flow Domain: Reference Frame
  - [Analysis] [Reference Frame]





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### **3D CFD ANALYSIS**

#### **CFD Solution Setup**



- Define **Flow Domain:** *Heat Source (total loss value)* 
  - [Analysis] [Heat Source]
    - Winding loss (straight part): 448.47 W

#### Please refer to the pages 15-16 for the winding loss (Joule loss) computation



Results Electronics Advanced Inspect Automation Extensions 🕂

### **3D CFD ANALYSIS**

#### **CFD Solution Setup**

- Define Flow Domain: Heat Source (total loss value)
  - [Analysis] [Heat Source]
    - Winding loss (end windings)
      - C.S.: 316.67 W
      - O.C.S.: 214.17 W

Please refer to the pages 15-16 for the winding loss (Joule loss) computation

	Files	Measure Home	Move	Material Material	Coordinate	Initial Condi	tion Heat Source	e Referenc Frame	ce Componer	nts
(total los	ss valu	ıe)								
			Heat Source :::			::: ð×				
	122		Name	Н	eatSource_EWOCS		Salact	the ho	dv	
			Select bodies	E	ndWinding_OCS					
		K	<ul> <li>Heat source de</li> </ul>	ensity	1.5	5 W/mm3	Enavvin	ang_c	JUS	
			<ul> <li>Heat source or</li> </ul>	n each body	2	14.17 W				
			<ul> <li>Distributed hea</li> </ul>	t source density t	able					
h	/		Makabasharatian	N	one v C	reate				
		<b>N</b>	Multiplier function	N	one	* M				
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				Sel	ect the bo	odv	Name		HeatSource_E	EWCS
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				Lina		_00	<ul> <li>Heat source</li> </ul>	density		1.5 W/mm3
							<ul> <li>Heat source</li> </ul>	on each body		316.67 W
						$\checkmark$	<ul> <li>Distributed h</li> </ul>	eat source den	sity table	
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Z Y	×		,					<u>A</u> pply	<u>О</u> К	<u>C</u> ancel
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Geometry Mesh Analysis

Solutions

Sketch



### **3D CFD ANALYSIS**

#### **CFD Solution Setup**



- Define Flow Domain: Heat Source (total loss value)
  - [Analysis] [Heat Source]
    - Magnet: 0.34 W

Please refer to the page 17 for the magnet loss (Joule loss) computation





- Define Flow Domain
  - Reference Frames + Heat Sources (total loss value)



- Define Flow Domain: Heat Source (nodal mapping)
  - · Loss import: stator and rotor losses
    - [File] [Import] [Solver Input File]



### **3D CFD ANALYSIS**

#### **CFD Solution Setup**

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- Define Flow Domain: Heat Source (nodal mapping)
  - Loss import: stator and rotor losses Imported meshed models for iron losses Assembly Browser A S Material Name Assembly 🖃 🏰 3D IkerMAQ CFD Mesh.g.. Air 🕼 Air Air\_Int\_1 Air Air Int 2 Air AirGap\_Fixed Air AirGap Rotating Air Coil IkerMAQ Copper EndWinding\_CS kerMAQ\_Copper EndWinding OCS kerMAQ Copper Housing IkerMAQ Aluminiu... Insulation IkerMAQ Epoxy Magnet IkerMAQ Magnet Rotor IkerMAQ\_M800\_6\_ Shaft IkerMAQ\_Aluminiu\_ 0 Stator kerMAQ\_M800\_6.. 0 Wedge Air IkerMAQ\_CFD\_RotorLosse\_ Body 2 IkerMAQ\_CFD\_StatorLosse. Body 2 92 / & / Ø / @ / 🖋 / 🍕 🕠

- Define Flow Domain: Heat Source (nodal mapping)
  - Loss import: stator and rotor losses
    - Visualize both the import bodies (stator and rotor losses) and the original bodies to check if the bodies are well covered



- Define Flow Domain: Heat Source (nodal mapping)
  - · Loss import: stator and rotor losses
    - Translate respectively the imported bodies (stator and rotor losses)





- Define Flow Domain: Heat Source (nodal mapping)
  - Loss import: stator and rotor losses
    - Translate respectively the imported bodies (stator and rotor losses)





### **3D CFD ANALYSIS**



- Define Flow Domain: Heat Source (nodal mapping)
  - Load Mapping ..... 3 × Loss mapping: stator losses ٠ Method Data Table Data Table + Model [Analysis] – [Tools] – [Mapping] • Results Data + Model Heat source density Data type Interpolation method Closest Point \* Map to Element Noda Input Data format Nastran bulk data Select the loss file "IkerMAQ\_CFD\_StatorLosses.nas" Data file FD StatorLosses.nas Import. Data unit system MKS (m kg N s) Select the imported body **StatorLosses** Body StatorLosses Plot input data as contour Influence Distance Auto calculate User defined Select the body to be mapped: Stator Map to bodies/faces Stator Create Load Heat source Туре Define the generated result name: "HeatSource\_Stator" Name HeatSource Stator Map Data. Mapping done successfully. Click on Map Data Section Export: OK Export <u>Cancel</u>



### **3D CFD ANALYSIS**

#### **CFD Solution Setup**



- Define **Flow Domain**: Heat Source (nodal mapping) •
  - Loss mapping: rotor losses ٠
    - [Analysis] [Tools] [Mapping] •

Select the loss file "IkerMAQ CFD RotorLosses.nas"

Select the imported body RotorLosses

Select the body to be mapped: Rotor

Define the generated result name: "HeatSource\_Rtator"

OK

#### Mapping done successfully.





Heat source density

~

Import...

Cancel

Closest Point

Element Noda

Nastran bulk data

MKS (m kg N s)

Export

RotorLosses

FD\_RotorLosses.nas

Plot input data as contour

Method Data Table Data Table + Model

Data type

Map to

Input Data format

Data file

Body

Data unit system

Interpolation method

Results Data + Mode





Data Table + Model
 Results Data + Model

Method : Data Table

Data type

Map to

Input

Interpolation method

Data format

Heat source density

Closest Point

Element Nodal

Nastran bulk data

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### **3D CFD ANALYSIS**

- Define Flow Domain: Heat Source (nodal mapping)
  - · Loss mapping: stator and rotor losses



- Define Flow Domain
  - Reference Frames + Heat Sources (total loss value + nodal mapping)







- Define Flow Boundaries: Inlet
  - [Analysis] [Inlet]



File View	Solutions Sket	ch Geometry M	lesh Analysis R	esults Electronic	cs Advanced	Inspect Automati	on Extension	<b>15</b> -{}-							
	0		FEAI		T=0			<b>B</b>	E		V=0	E	62		S C
Files	Measure	Move	Material	Coordinate	Initial Condition	Heat Source	Reference Frame	Components	Inlet	Outlet	Wall	Slip	Symmetry	Advanced	Radiation
	Home		Material							Boundary Co	onditions 🔻				

- Define **Flow Boundaries**: Outlet
  - [Analysis] [Outlet]



#### **CFD Solution Setup**

•



- Define Flow Boundaries: Slip
  - [Analysis] [*Slip*]

Slip 1	Slip :×			
	Name Slip_1			
	Select faces .34297,34136,34278,34111,33957			
	Surface Output ⇒			
	Apply QK Cancel			
	_			
		Select faces of Slip_1		
			× me	Slip 1
			~	
	The second se			
	x			
	Z			
	V Y			ALIAIR



- Define Flow Boundaries: Slip
  - [Analysis] [*Slip*]
    - Slip 2 and 3

Slip         3 ×           Name         Slip_2           Select faces         17655,37507,14216,15771,15890           Surface Output <>            Apply         QK         Cancel	Select faces of Slip_2 (all 22 boundary faces on one side)	Slip       Slip_3         Name       Slip_3         Select faces       16443,16513,37593,15776,15885         Surface Output %       Apply         Apply       QK         Cancel
Z X Y		X Y Z



### **3D CFD ANALYSIS**

- Define Flow Boundaries
  - Inlet + Outlet + Slip



<u>C</u>ancel

<u>0</u>K

### **3D CFD ANALYSIS**

#### **CFD Solution Setup**

- Define Solution Settings •
  - Define Solver Settings ٠



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		Value		
Offs	ets			_
	Absolute pressure offset	0 MPa		
	Absolute temperature offset	0 K		
a Aut	o Solution Strategy		Ma in 100 - 100 - 100 - 100	
	Maximun no. of time steps	150	Maximum no. of time steps: 150	
	Initial time increment	1E+10 s	Convergence tolerance: 0.002	
	Convergence tolerance	0.002		
	Number of krylov vectors	10		
	Relaxation factor	0.3		
	Flow	True		
	Turbulence	True		
	Temperature	True		
	Temperature flow	<ul> <li>False</li> </ul>		
Adv	anced Solution Strategy			
<u> </u>	How Stagger			
	Temperature Stagger			
⊐ Res	tart Parameters			
	Restart from	None		<b>_</b>
Def	ault Wall Parameters			
	Wall velocity type	Match Me	sh Velocity	¥
	Thermal condition	Applied Flu	DX	<b>  v</b>
	Heat flux	0 W/mm2		
	Turbulence wall type	Wall Funct	ion	-
	Roughness height	0 mm		
	Wall function heat flux factor	1		
(	Gap	0 mm		
	Gap factor	1		
(	Crease angle	90 deg		
	Split internal surfaces	True		

#### **CFD Solution Setup**

- Define Solution Settings
  - Define Result Request



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- Define Solution Settings
  - Define Format and Execute Options

<ul> <li>IncerNAQ_CFD_Analysis</li> <li>Meah</li> <li>Type: Stady State</li> <li>Sother Settings</li> <li>Read: Request</li> <li>Read: Request</li> <li>Read: Request</li> <li>Bound</li> <li>Deteic</li> <li>Export Options</li> <li>Bound</li> <li>Colapse</li> <li>Colapse</li> <li>Colapse Fatial</li> <li>HeatSource_EWOCS</li> <li>HeatSource_EWOCS</li> <li>HeatSource_Rotor</li> <li>Nov Boundaies</li> <li>Inite</li> <li>Sole:</li> <li>Sole:</li> <li>Result</li> </ul>	olutions	Name	Value	
Description:		<ul> <li>Export Options Auto Wall Write mesh as : Pressure Refer</li> <li>Solver Options Number of Proc Additional Argu</li> </ul>	v True sets v True ence Node v True ments	Define the processor number (depends on the running compute
		Description:		



- Final CFD solution setup
  - Flow Domain + Flow Boundaries + Solver Settings





- Final CFD solution setup
  - Save the project [File] [Save As]
    - Save the project as "IkerMAQ\_CFD\_PhyDef"



		 -		
My Computer	Name	- 6	Size	Туре
buang	kerMAQ_CFD_CADModel.slb		3.65 Mil	B slb File
indung	kerMAQ_CFD_Mesh.slb		204Mil	B slb File
	4			



#### **CFD Solution Setup**

63

- Solve the CFD simulation project
  - Right click on the "Solutions" and select the solving folder for AcuSolve



☞<u>Notes:</u>

The solving process takes about 45 min depending on the computer on which it is run.

Results means that the solving process is completed
 Results means that the solving process is in progress



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### **3D CFD ANALYSIS**

#### **CFD Solution Setup**

64

- Solve the CFD simulation project
  - Temperature distribution



- Solve the CFD simulation project
  - Streamline results





- Solve the CFD simulation project
  - Save the project [File] [Save As]
    - Save the project as "IkerMAQ\_CFD\_Solved"







#### CONCLUSION



#### CONCLUSION

- In this application case, a **P**ermanent **M**agnet **S**ynchronous **M**achine (IkerMAQ motor) is modeled in **Flux** for 2D electromagnetic analysis.
- All the eMotor loss information computed by Flux serve as Heat Source in AcuSolve to run CFD analysis.
- The eMotor CFD analysis is simulated with **AcuSolve** (via **SimLab**) .Preliminary CFD analysis results are reasonable. The temperature simulation results are close to the actual values.



# **THANK YOU**

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