

電機設計之優化分析-案例探討

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11/26/2015

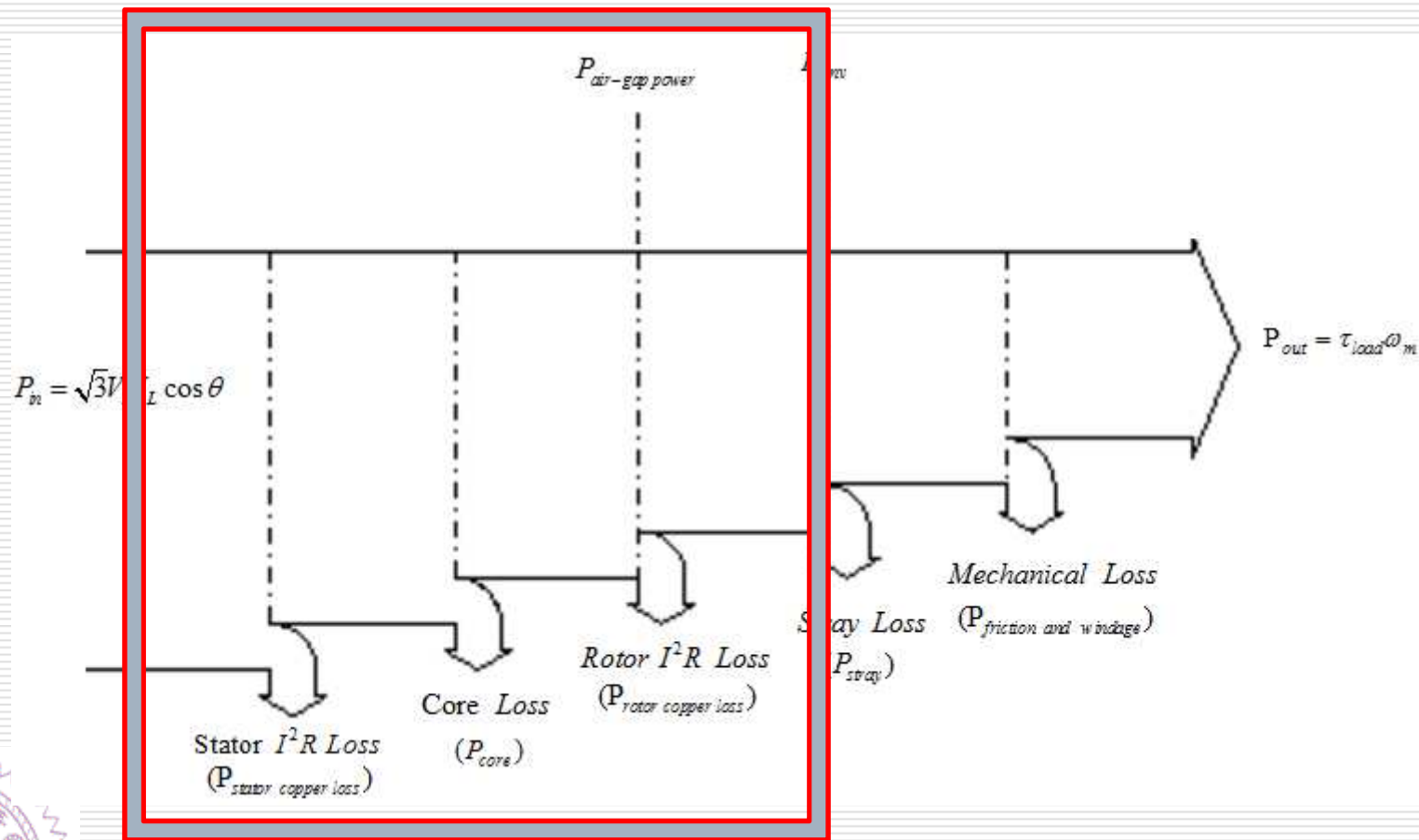


Outline

- ANSYS RMxpert- design pack for major electric machines in mathematical formulae.
- SmartDo- script settings for IM optimization with constraints.
- Case study- optimal design of Induction motors
- Concluding Remarks



2D FEM for optimization



Electrical machine Design: RMxprt

Inputs

- Dimensions
- Materials
- Windings
- ...

Driving conditions

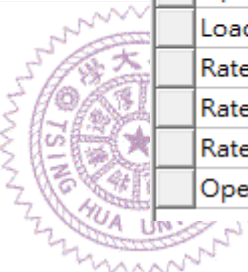
- Rated speed
- Rated power
- Current input
- ...

Outputs

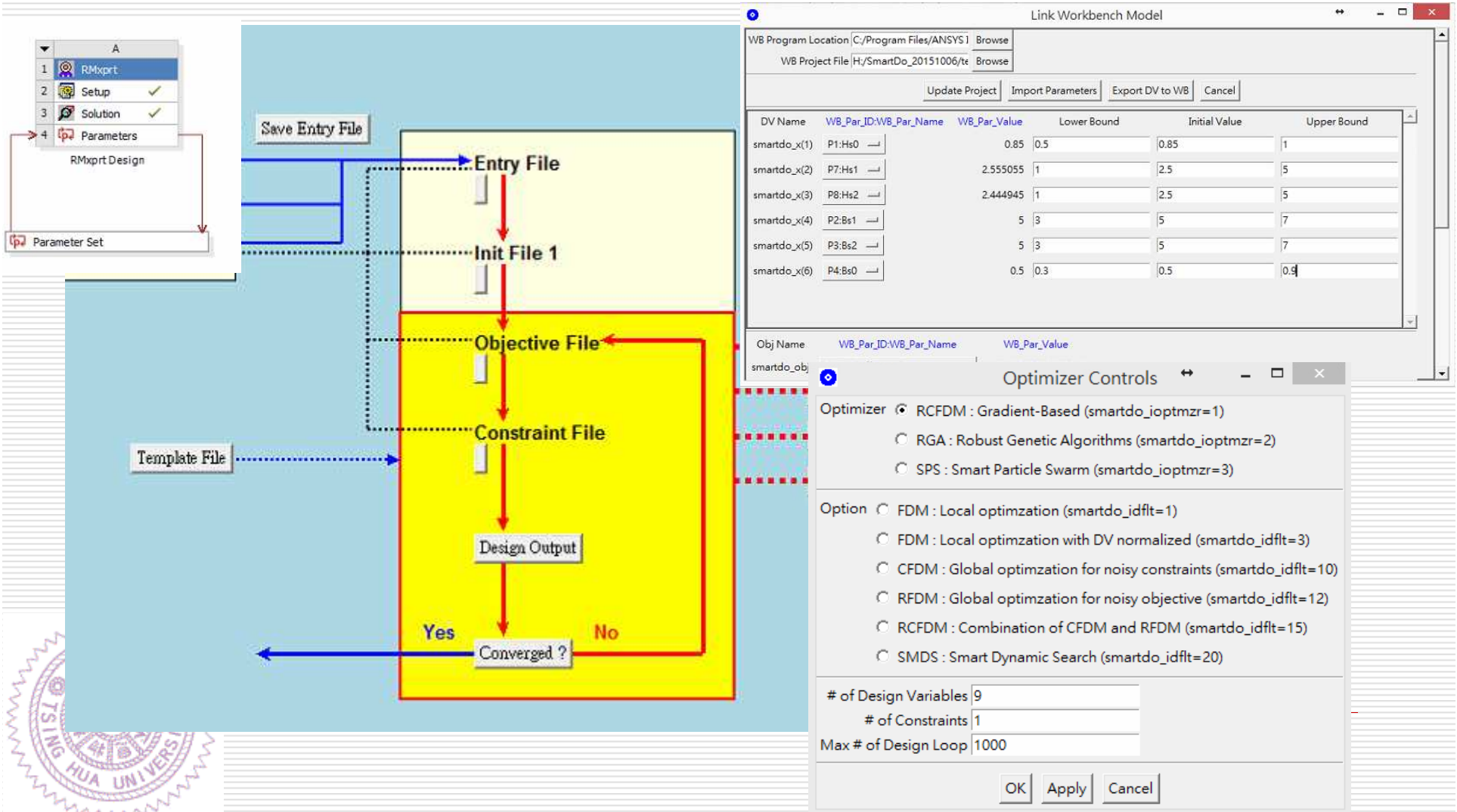
- Air gap flux density
- Output torque
- Efficiency
- ...

Diagram labels: stator yoke height, slot width

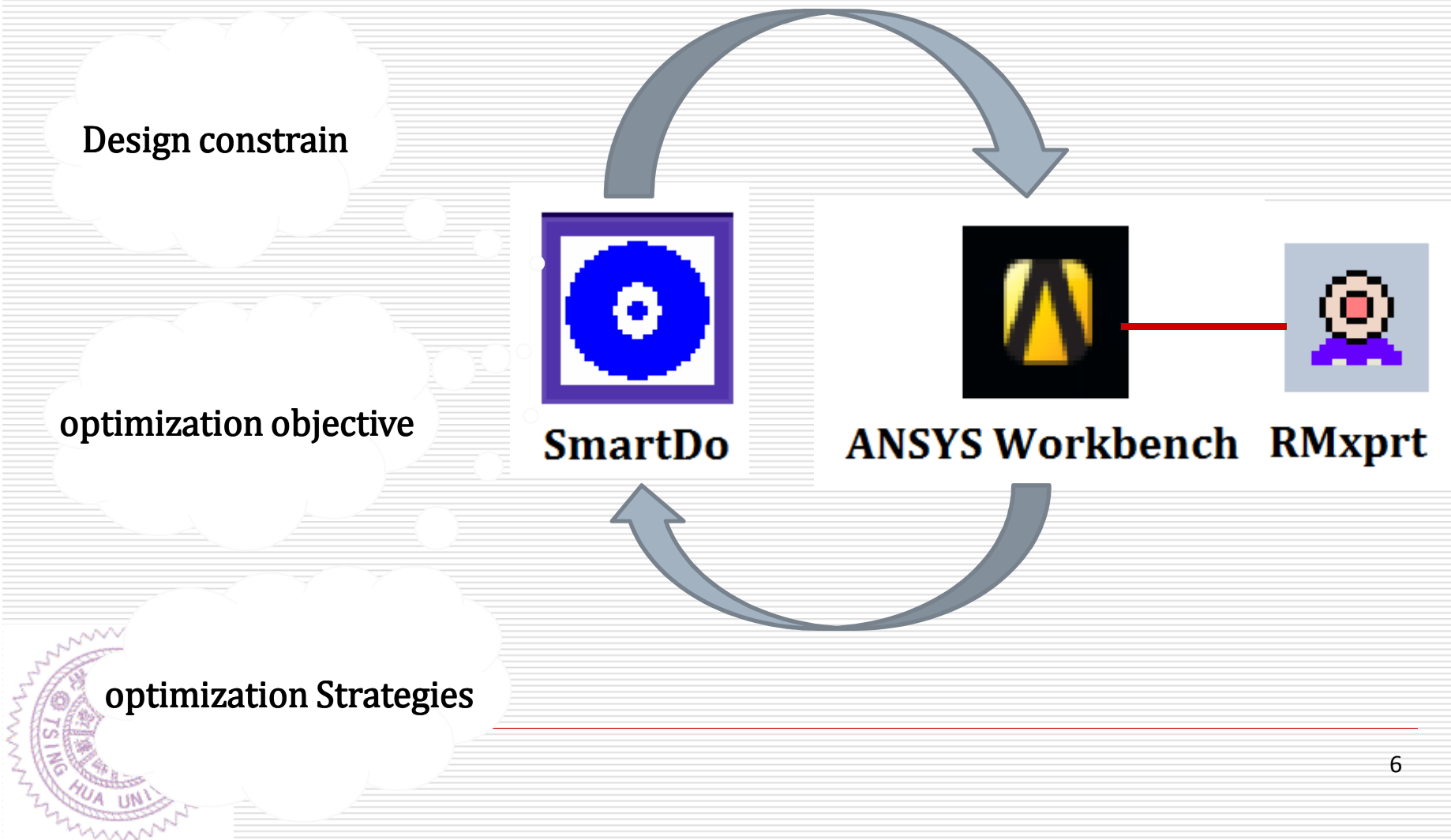
Name	Value	Unit	Evaluated
Name	Setup2		
Enabled	<input checked="" type="checkbox"/>		
Operation T...	Motor		Motor or generator <input checked="" type="checkbox"/>
Load Type	Const Speed		Mechanical load ty... <input type="checkbox"/>
Rated Outp...	7460	W	7460W Rated mechanical ... <input type="checkbox"/>
Rated Volta...	220	V	220V Applied or output r... <input type="checkbox"/>
Rated Speed	3523.2	rpm	3523.2rpm Given rated speed <input type="checkbox"/>
Operating T...	69.8	cel	69.8cel Operating tempera... <input type="checkbox"/>



SmartDo Optimization

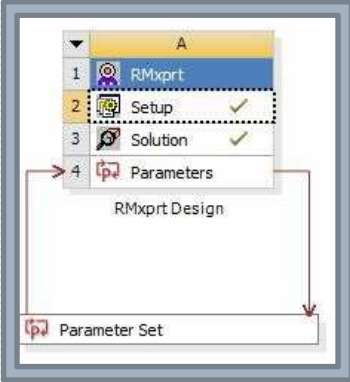


SmartDo optimization with RMxpert

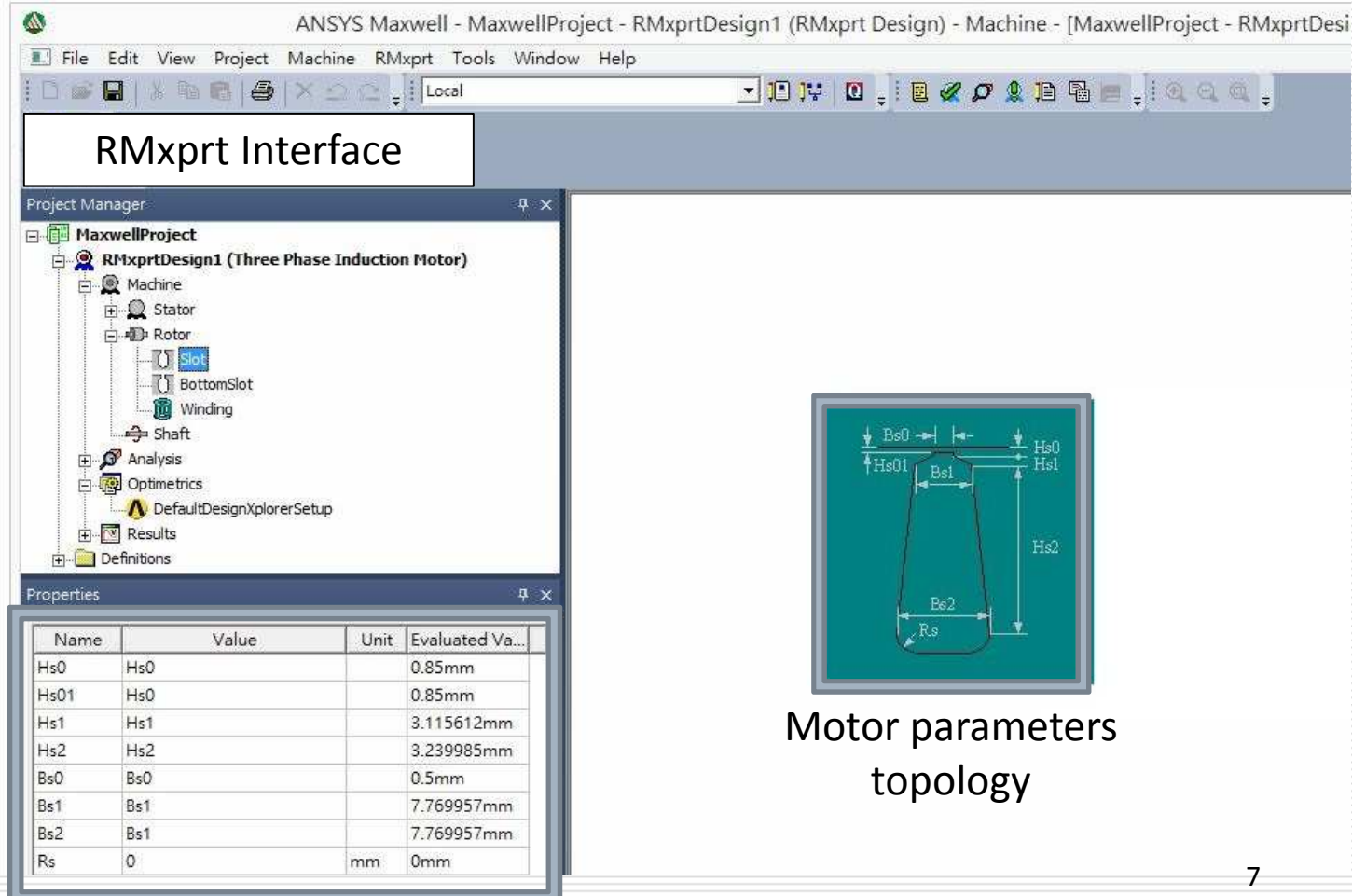


Parameter setting in ANSYS WB

Project Schematic

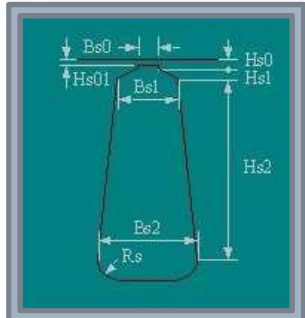


ANSYS WB Interface



RMxprt Interface

Name	Value	Unit	Evaluated Va...
Hs0	Hs0		0.85mm
Hs01	Hs0		0.85mm
Hs1	Hs1		3.115612mm
Hs2	Hs2		3.239985mm
Bs0	Bs0		0.5mm
Bs1	Bs1		7.769957mm
Bs2	Bs1		7.769957mm
Rs	0	mm	0mm



Motor parameters topology

Motor parameters setting



Parameter setting for constraints

The screenshot shows a software interface with a table of parameters and constraints. A blue arrow points from a text box to the 'Allowable Value' field of a constraint.

Obj Name	WB_Par_ID:WB_Par_Name	WB_Par_Value
smartdo_obj	P5:100-EfficiencyParameter	8.576999999999982

Constraint	WB_Par_ID:WB_Par_Name	WB_Par_Value	Operator	Allowable Value
smartdo_cnstrn(1)	P8:RotorBarMaterialWeightParameter	0.567173	<	0.5672

Constrain conditions:
Break-Down Torque
Rotor weight
Power factor
...

Quantity: EfficiencyParameter

Function: <none>

Update Report
 Real time [Update]

Output Variables... Options... [New Report] [Apply Trace] [Add Trace] [Close]



Design parameters in SmartDo

Outline of All Parameters

Design parameters			C	D
			Value	Unit
1				
2	Input Parameters			
3	Rmixprt Design (A1)			
4	P2	Bs1	7.77	
5	P7	Hs1	3.1156	
6	P9	Hs2	3.24	
7	P10	BHs0	0.91802	
8	P11	BBS0	3.8123	
9	P12	BHs2	8.5018	
10	P13	BBS1	7.7298	
11	P14	BBS2	2.0921	
12	P15	RotorID	42	
*				
14	Output Parameters			
15				
16	P5	100-EfficiencyParameter	8.5322	
17	P6	10-BreakDownTorqueRatioParameter	4.1823	
18	P8	RotorBarMaterialWeightParameter	0.56959	
*				
20	Charts			

WB Program Location: C:/Program Files/ANSYS1 Browse

WB Project File: H:/SmartDo_20151017/G Browse

Update Project Import Parameters Export DV to WB Cancel

DV Name	WB_Par_ID:WB_Par_Name	WB_Par_Value	Lower Bound	Initial Value	Upper Bound
smartdo_x(1)	P2:Bs1	5	3	5	10
smartdo_x(2)	P7:Hs1	2.56	0.5	2.56	5
smartdo_x(3)	P9:Hs2	2.4	0.5	2.4	5
smartdo_x(4)	P10:BHs0	2.7	0.5	2.7	5
smartdo_x(5)	P11:BBS0	1.33	1	1.33	5
smartdo_x(6)	P12:BHs2	8.8	5	8.8	12
smartdo_x(7)	P13:BBS1	7.742871	5	7.742871	10
smartdo_x(8)	P14:BBS2	4.51003	2	4.51003	10

Obj Name WB_Par_ID:WB_Par_Name WB_Par_Value

smartdo_obj P5:100-EfficiencyParameter 8.576999999999982

Constraint	WB_Par_ID:WB_Par_Name	WB_Par_Value	Operator	Allowable Value
smartdo_cnstrn(1)	P8:RotorBarMaterialWeightParameter	0.567173	<	0.5672

optimization objective and Design constrain



Optimization feedback to ANSYS WB

```

SmartDO_06_0
----- EVALUATING FUNCTION VALUES : 1
----- EVALUATING FUNCTION VALUES : 2
----- EVALUATING FUNCTION VALUES : 3

***** CYCLE 5 COMPLETED; OBJ = 8.5375e+000; UMAX = 6.2588e-004

Artificial OBJ = 8.5449e+000

***** OPTIMIZATION LOOP CONVERGED !

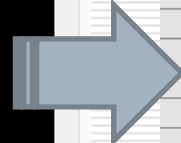
***** smartdo exeopt : END OF OPTIMIZATION LOOP
----- END OF OPTIMIZATION TIME : Mon Nov 02 20:25:28 2015

----- OPTIMIZER ENDING TIME : Mon Nov 02 20:25:28 2015

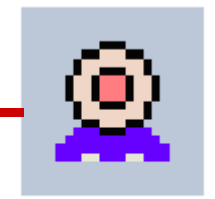
----- TIME SPENT FOR FULL OPTIMIZATION CYCLE IS 4524 SECONDS
    
```

Outline of All Parameters

	A	B	C	D
1	ID	Parameter Name	Value	Unit
2	[-] Input Parameters			
3	[-] RMxprt Design (A1)			
4	P2	Bs1	7.4569	
5	P7	Hs1	3.2116	
6	P9	Hs2	3.2184	
7	P10	BHs0	0.5	
8	P11	BBS0	3.8113	
9	P12	BBS1	7.5505	
10	P13	BBS2	3.3487	
11	P14	BHs2	7.7962	
*	New input parameter	New name	New expression	
13	[-] Output Parameters			
14	[-] RMxprt Design (A1)			
15	P5	100-EfficiencyParameter	8.5238	
16	P6	10-BreakDownTorqueRatioParameter	4.2008	
17	P8	RotorBarMaterialWeightParameter	0.5731	
*	New output parameter		New expression	
19	Charts			

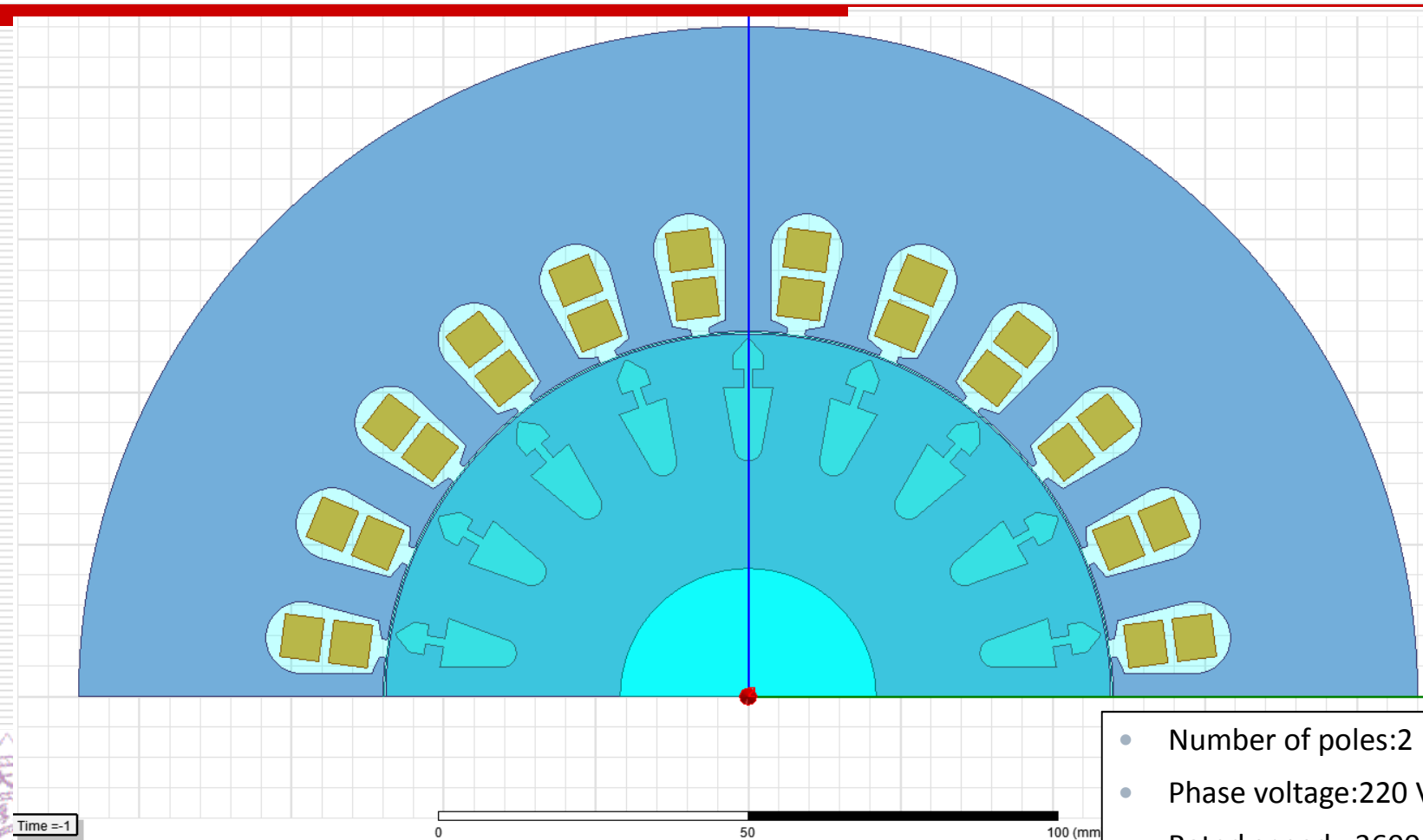


Result rewrite to ANSYS WB automatical



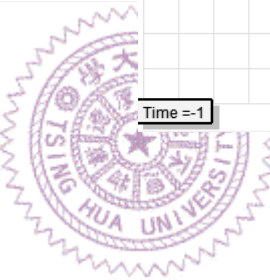
ANSYS Workbench RMxprt

Induction Machine Design Optimization

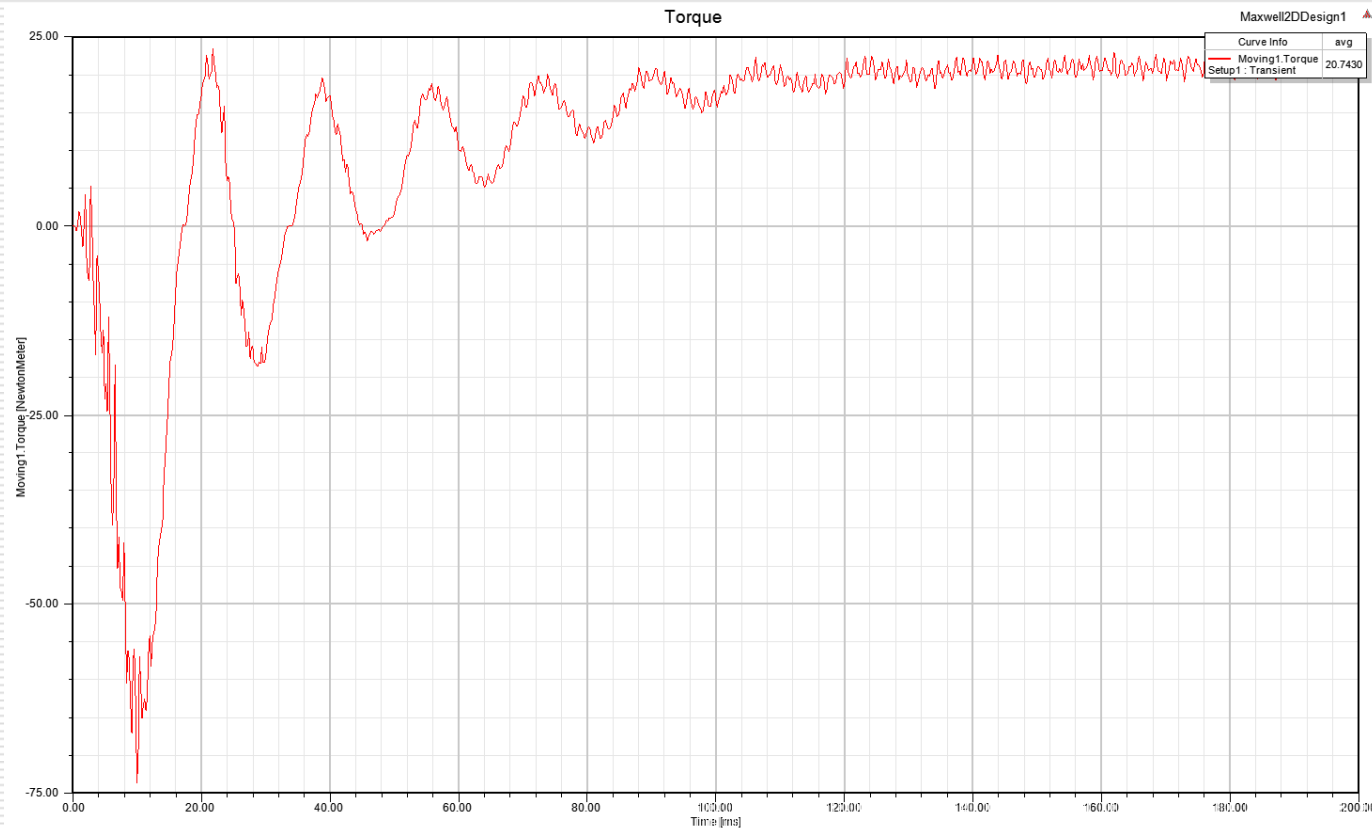


- Number of poles:2
- Phase voltage:220 V
- Rated speed : 3600 rpm
- Rated output Power: 10 HP

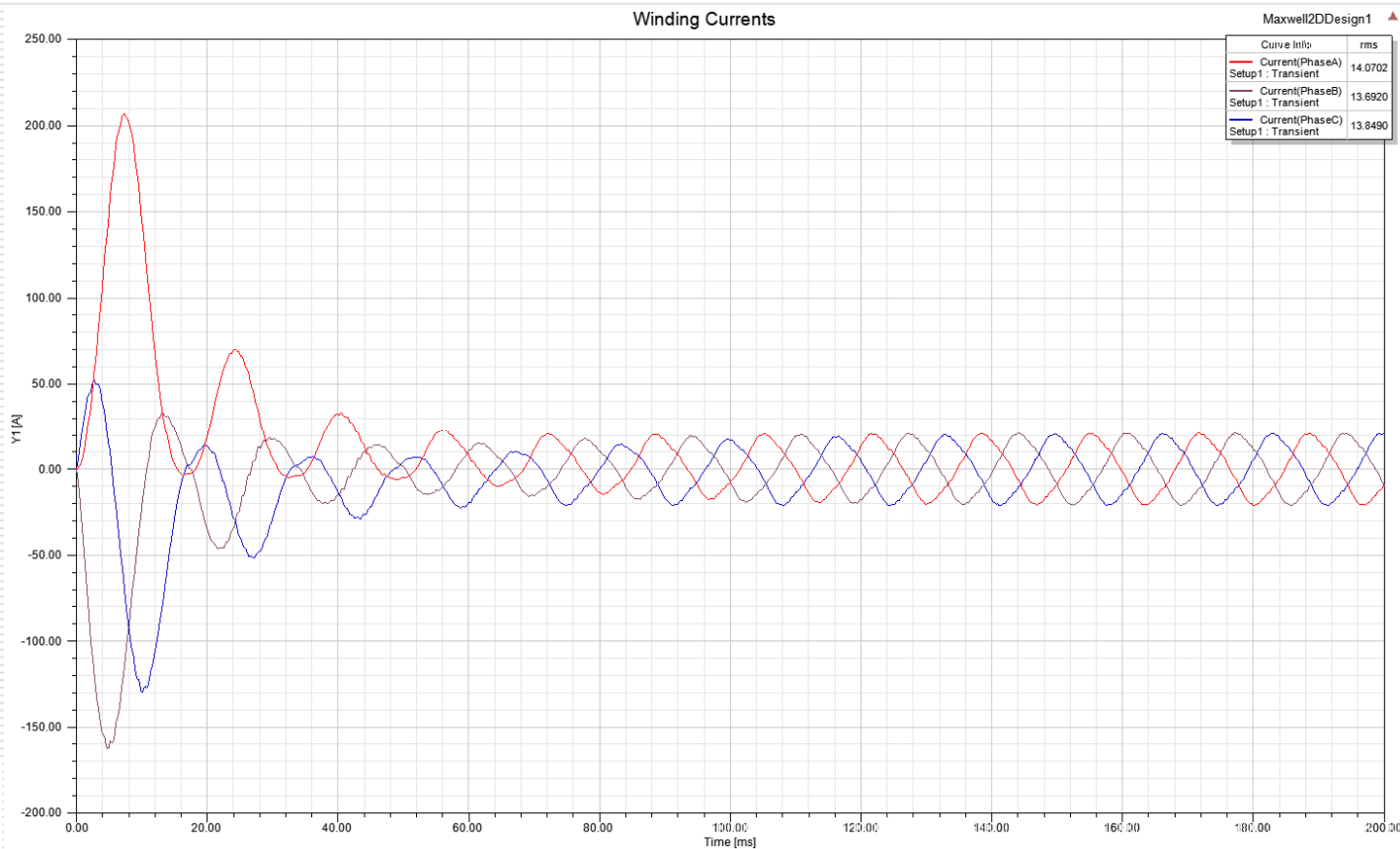
Induction motor Design A



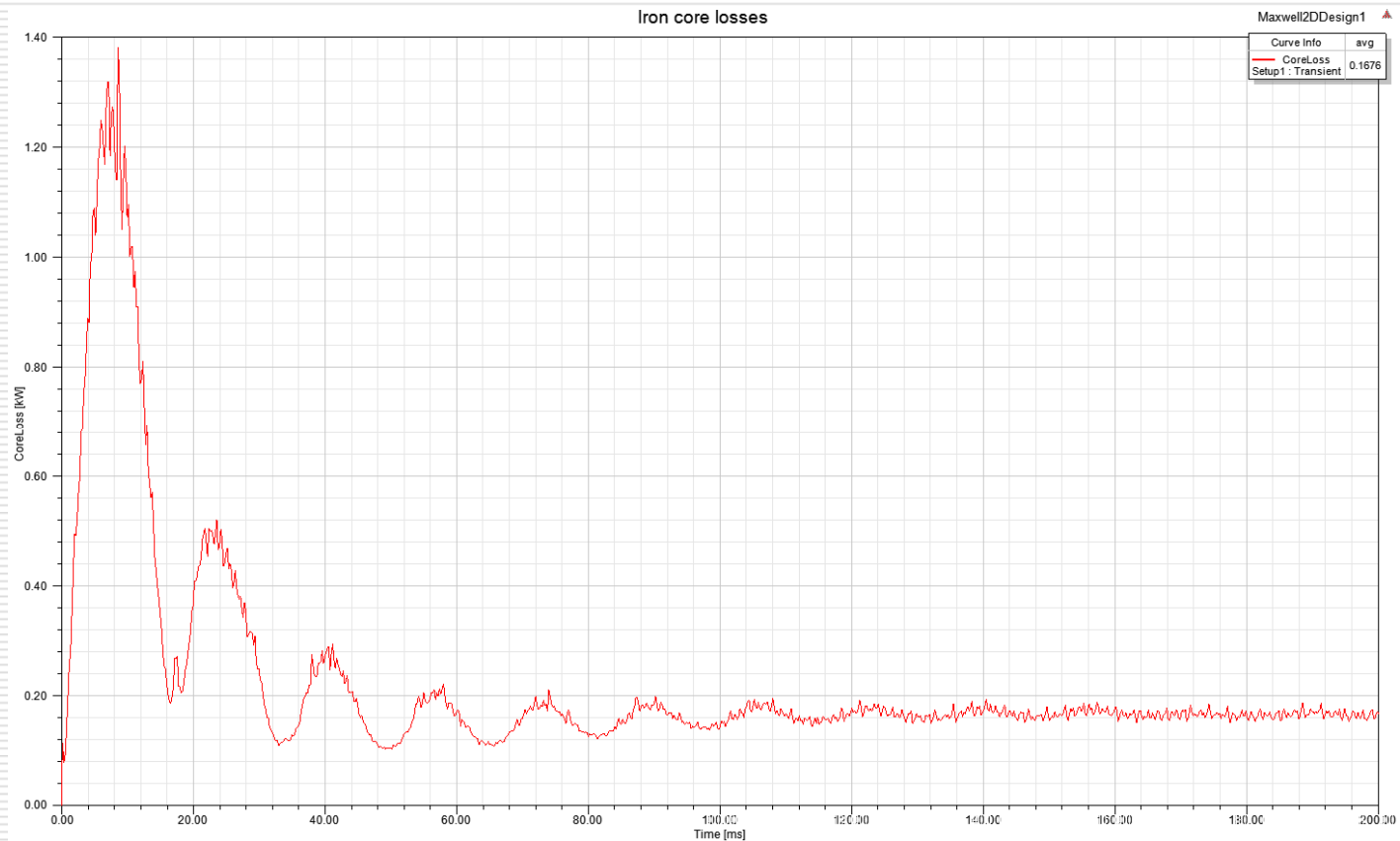
Output Torque for Design A @ 3,525rpm



Line Currents for Design A @ 3,525rpm



Core Losses for Design A @ 3,525rpm

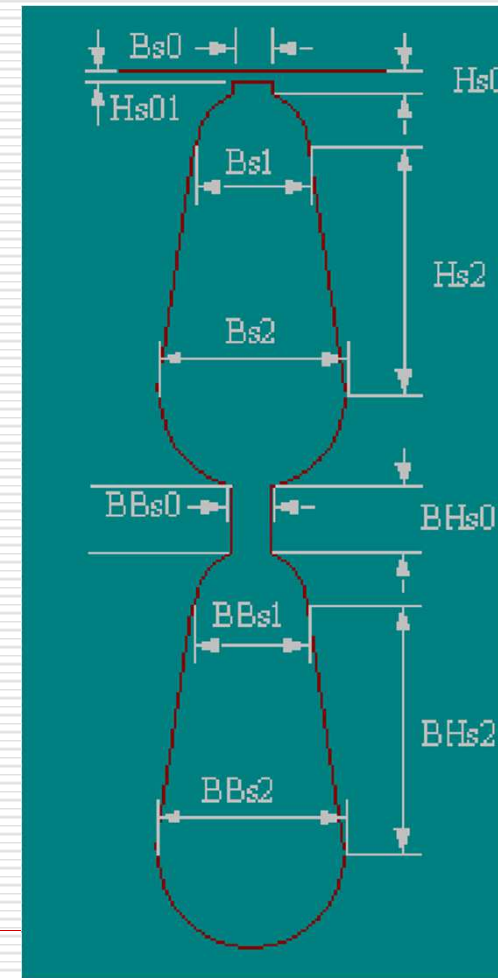
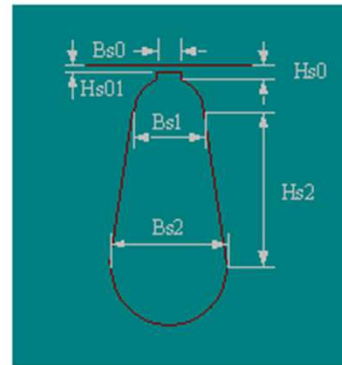


RMxprt Report for IEEE-112-B

	RMxprt design	IEEE-112-B	Percentage error(%)
Rated Efficiency (%)	91.3756	91.37	0.0044
Output torque (N.m)	21.0513	20.176	4.3383
Iron core losses (W)	140.97	156.289	9.8017
Stator I^2R losses(W)	198.387	198.39	0.0015
Rotor I^2R losses(W)	171.309	169.47	1.0851
Friction and windage losses (W)	91.93	91.93	0
Stray-load losses (W)	115.15	115.15	0
Total losses (W)	733.065	715.91	2.3963



Optimization Approach - Slot Geometry



Project Manager

- KSmotor_AL_RM_WBTEST5
 - RMxprrDesign1 (Three Phase Induction Motor)
 - Machine
 - Stator
 - Rotor
 - Slot
 - BottomSlot
 - Winding
 - Shaft
 - Analysis
 - Setup1
 - Optimetrics
 - Results
 - Definitions

Properties: KSmotor_AL_RM_WBTEST5 - RMxprrDesign1 - Machine

Slot

Name	Value	Unit	Evaluated Va...	Description
Hs0	HS0	0.8mm		Slot dimension: Hs0
Hs01	HS01	0.8mm		Slot dimension: Hs01
Hs2	HS2	5mm		Slot dimension: Hs2
Bs0	BS0	2mm		Slot dimension: Bs0
Bs1	BS1	5mm		Slot dimension: Bs1
Bs2	BS2	1mm		Slot dimension: Bs2

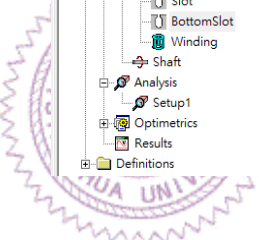
Project Manager

- KSmotor_AL_RM_WBTEST5
 - RMxprrDesign1 (Three Phase Induction Motor)
 - Machine
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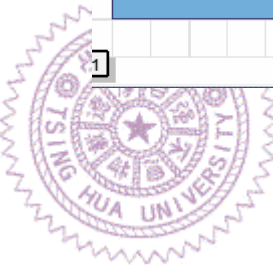
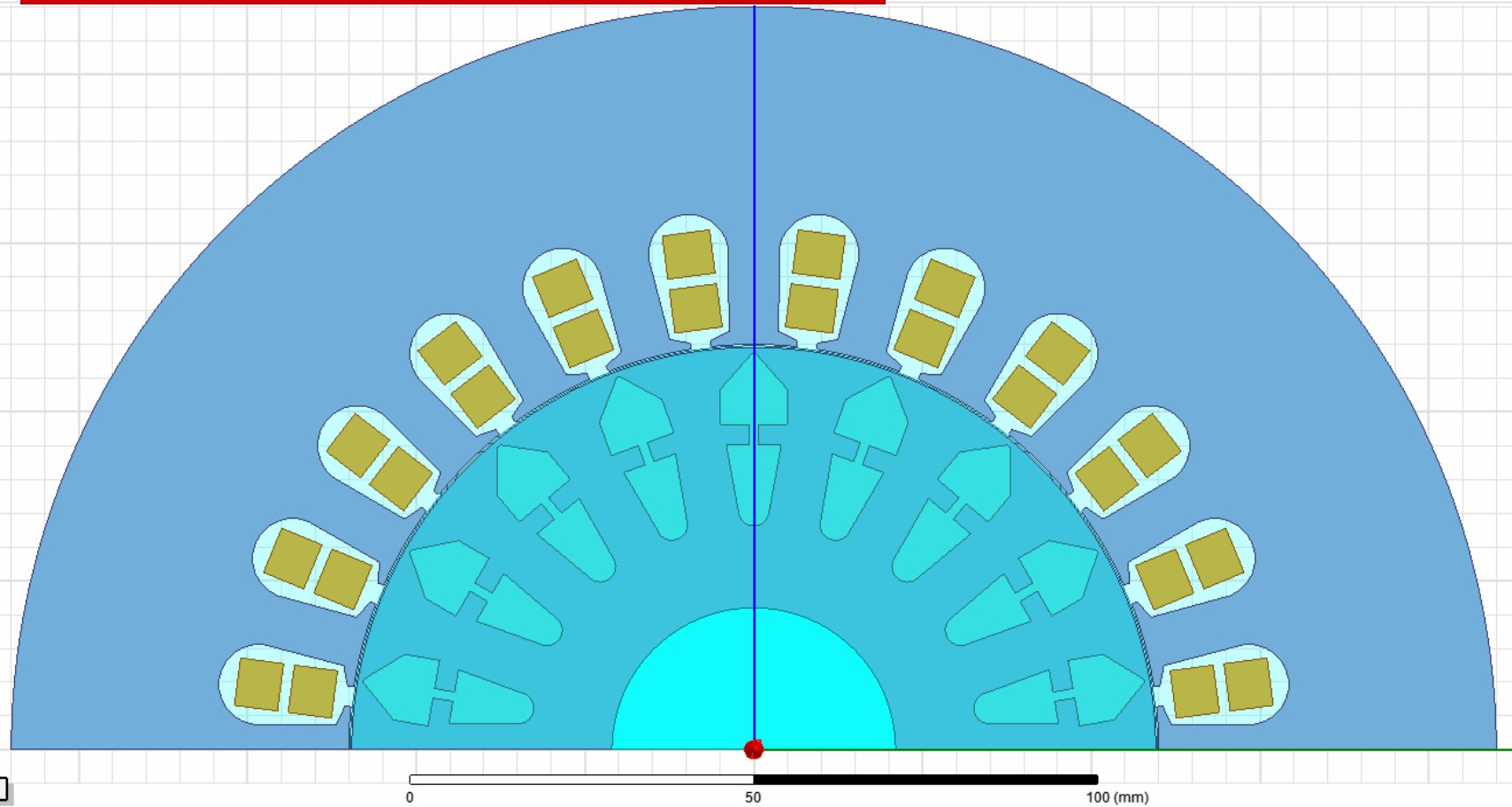
Properties: KSmotor_AL_RM_WBTEST5 - RMxprrDesign1 - Machine

Slot

Name	Value	Unit	Evaluated Va...	Description
Hs0	BHS0	1.5mm		Slot dimension: Hs0
Hs2	BHS2	10mm		Slot dimension: Hs2
Bs0	BBS0	1mm		Slot dimension: Bs0
Bs1	BBS1	6.67mm		Slot dimension: Bs1
Bs2	BBS2	3.3747mm		Slot dimension: Bs2



Topology after Optimization



Induction motor Design B with Rotor Slot shape optimization

SmartDo Optimization Results

Rated Efficiency (%)	91.3756	91.7423	0.3667
Output torque (N.m)	21.0513	20.0867	-4.8021
Iron core losses (W)	140.97	160.399	-12.1129
Stator I^2R losses(W)	198.387	189.111	4.9050
Rotor I^2R losses(W)	171.309	113.682	50.6914
Total losses (W)	733.065	671.489	9.17



Concluding Remarks

- Analytical calculations from RMxpert agree well to the IEEE 112B test report. Errors are mainly due to over-estimated iron core-losses. It could be improved by revision of iron core-loss measurement data.
- Resources limitation in CPU cores and memory capacity in ANSYS EM lead to impractical motor design optimization work. SmartDo add-on provides a better and faster way to implement motor design optimization.



Thank you and Q/A

