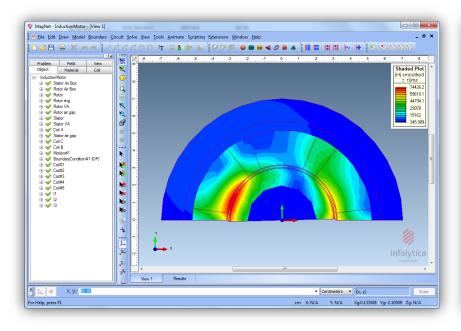
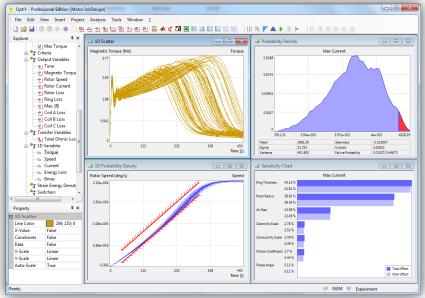


Robust Design of Induction Motor

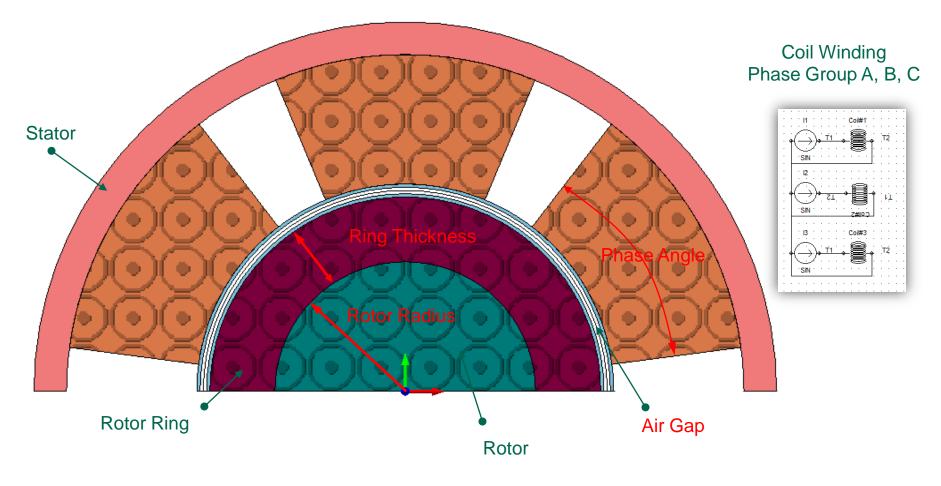




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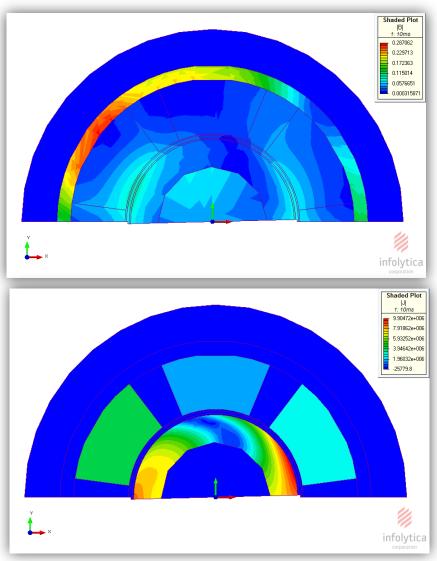


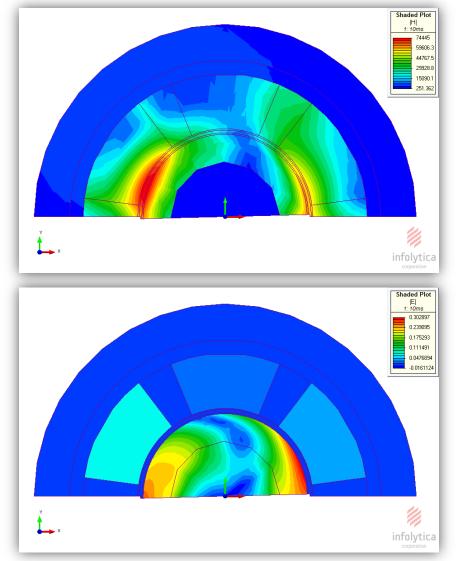
Design of Three Phase Induction Motor





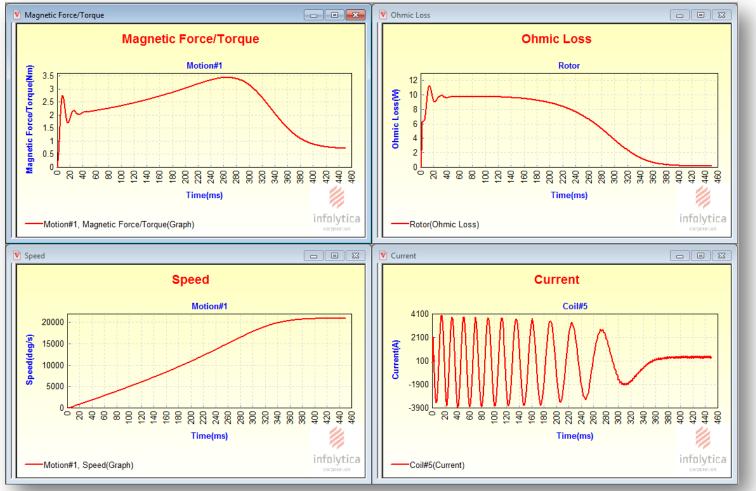
Field Simulation in Infolytica-MagNet







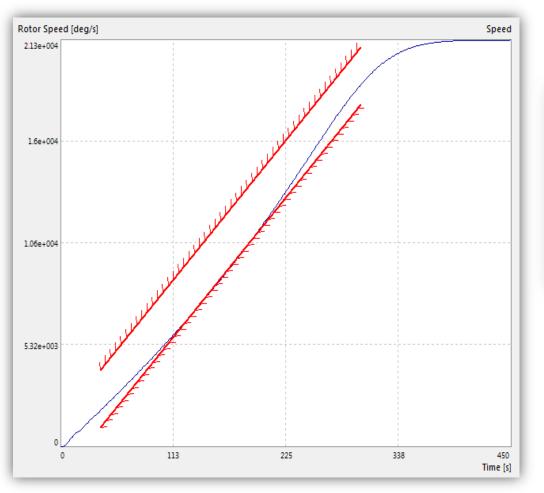
Dynamical Simulation in Infolytica-MagNet



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Design Specifications



Initial Design Parameters with its Uncertainty

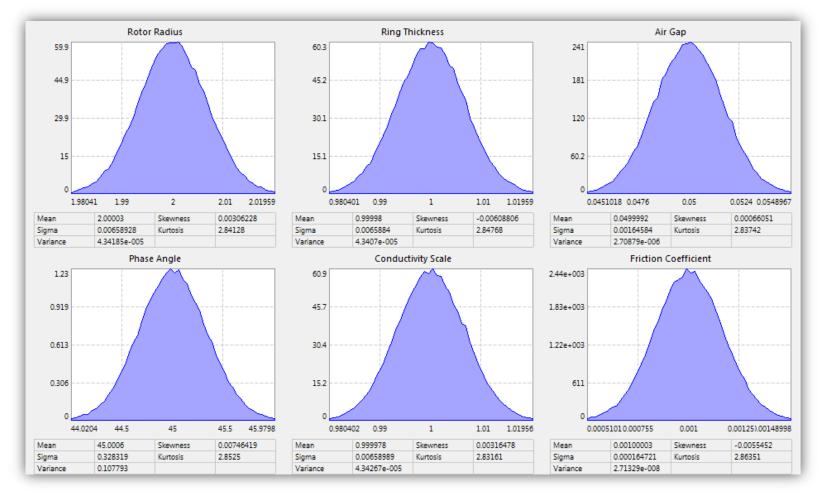
Name	Nominal	Tolerance	Unit
Rotor Radius	2	0.04	cm
Ring Thickness	1	0.04	cm
Air Gap	0.05	0.01	cm
Phase Angle	45	2	deg
Coercivity Scale	1	0.04	
Conductivity Scale	1	0.04	
Friction Coefficient	0.001	0.001	Nms/rad

- Max. Torque \leq 3.6 N*m
- Max. Current \leq 4020 A
- Max. Flux Density ≤ 0.115 T
- Max Energy Loss ≤ 345.000 W*s
- Corridor for Rotor Speed
 - \circ Rising = 65 deg/s²
 - \circ Bandwidth = 3000 deg/s

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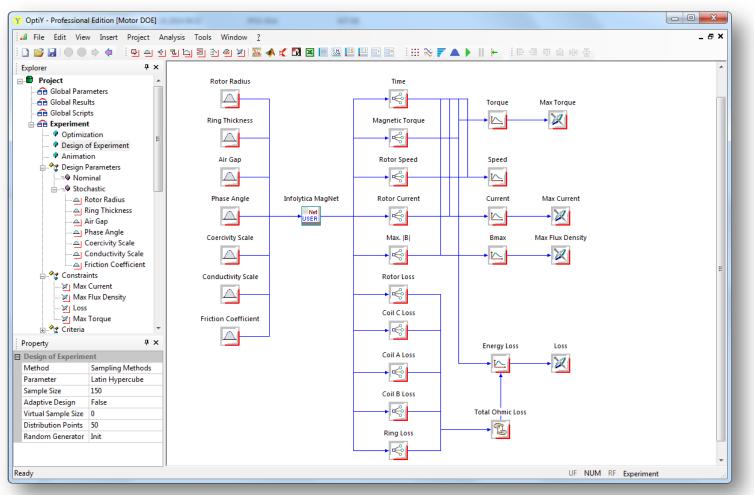
Stochastic Distributions of Design Parameters



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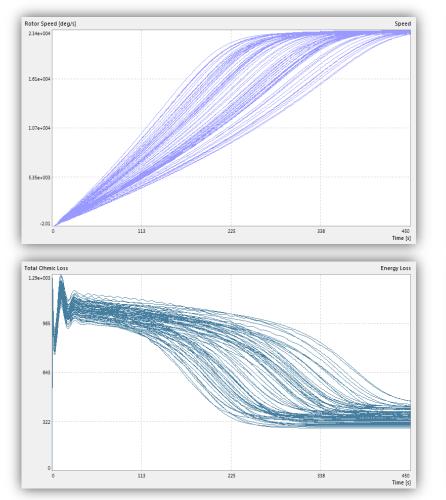


OptiY Process Work Flow

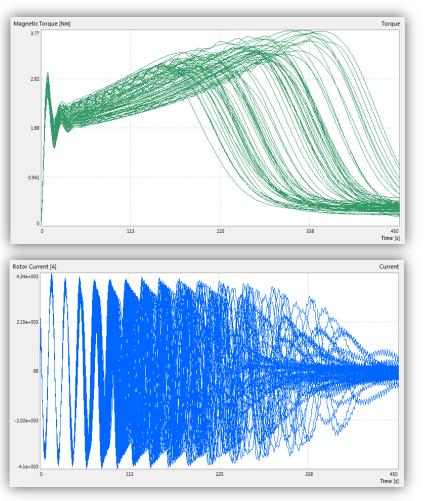


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Design of Experiment



Pham Slide 8

75 Calculations of Original Model in MagNet



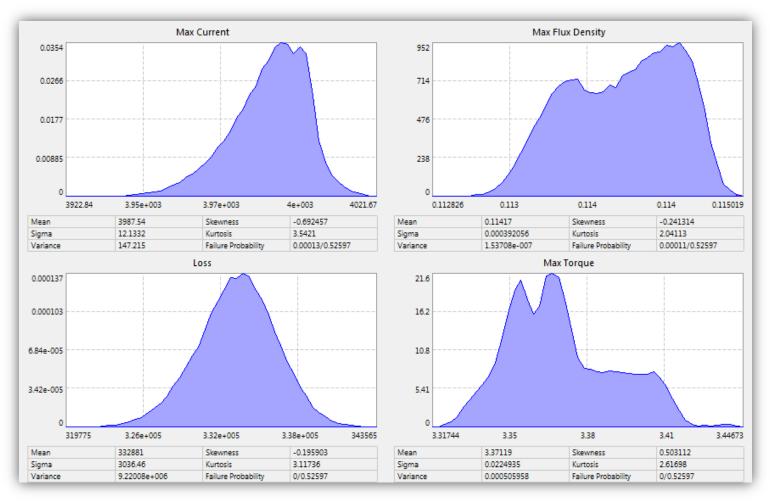
Probabilistic Simulation for Initial Design



Slide 9



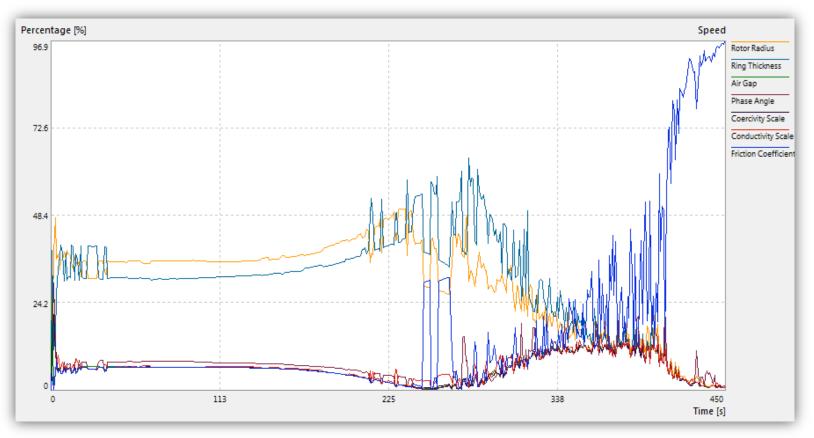
Probabilistic Simulation for Initial Design



Pham Slide 10



Sensitivity Study for Initial Design



- Rotor radius and ring thickness have most influence on rotor acceleration
- Friction coefficient is the most important factor on constant rotor speed



Max Current Max Flux Density 35.43 % **Ring Thickness** 78.57 % Ring Thickness 77.13 % 34.77 % Rotor Radius 27.26 % Rotor Radius 5.92 % 26.71 % 5.6 % Air Gap 14.45 % Conductivity Scale 5.54 % 14.08 % 5.09 % Coercivity Scale 6.11 % Coercivity Scale 4.07 % 5.85 % 3.77 % Conductivity Scale 6.05 % Friction Coefficient 2.62 % 5.79% 2.35 % Phase Angle 6.04 % Air Gap 2.47 % 5.79% 2.2% Friction Coefficient 5.93 % Phase Angle 2.44 % Total Effect Total Effect 5.68 % 2.18% Main Effect Main Effect Loss Max Torque Rotor Radius 45.18% Rotor Radius 94.35 % 44.31 % 92.83 % **Ring Thickness** 30.68 % Conductivity Scale 1.64 % 30.01 % 1.36 % Phase Angle 14.6 % Air Gap 1.63 % 14.14 % 1.35 % 1.62 % Friction Coefficient 9.13 % Coercivity Scale 8.74 % 1.34% Conductivity Scale 1.45 % 0.89 % **Ring Thickness** 1.16% 0.61% Coercivity Scale 0.27 % Friction Coefficient 0.75 % 0.48 % 0% 0.27 % 0.68 % Air Gap Phase Angle Total Effect Total Effect 0% 0.41 % Main Effect Main Effect

Sensitivity Study for Initial Design

Pham Slide 12



Robust Design Optimization

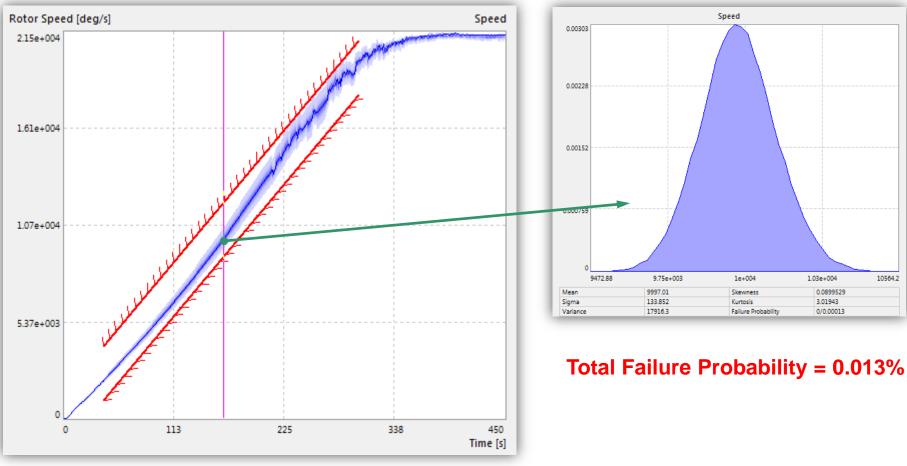
Calculator		Optimization Results:				
sqr(mean(Speed)-9995)		Robust Design Parameters				
Speed Max Current	sin asin Back Delete All	with its Uncertainty				
Max Flux Density Loss Max Torque						
Max Folgue	tan atan 7 8 9 /					
	abs exp 4 5 6 *	🚽 Design Parameter				
		Name	Nominal	Tolerance	Unit	
	In pow 1 2 3 -	Rotor Radius	1.87606281	0.04	cm	
	sqrt sqr 0 , +	Ring Thickness	1.06458141	0.04	cm	
	sqr U , +	Air Gap	0.0419933476	0.01	cm	
	Statistics	Phase Angle	45.9295363	2	deg	
		Coercivity Scale	1	0.04		
	Mean Sigma Variance Cost	Conductivity Scale	1	0.04		
		Friction Coefficient	0.001	0.001	Nms/rad	
Tes	t OK Cancel			-		

Robust Design Goal to Minimize the Failure Probability

Pham Slide 13



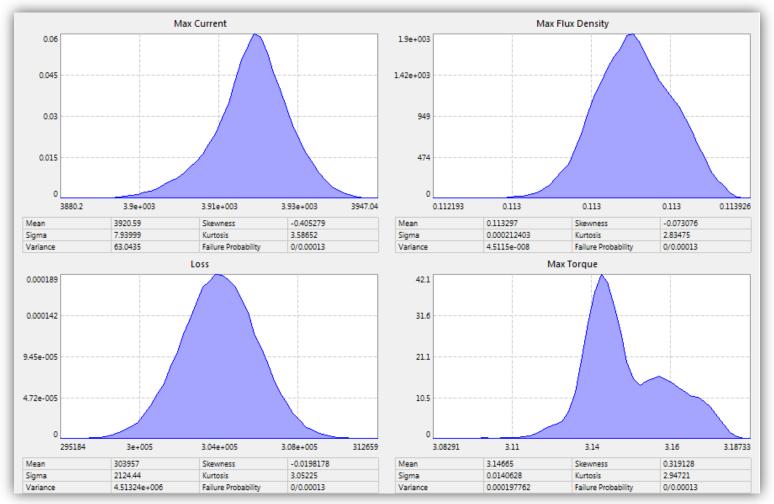
Probabilistic Simulation for Robust Design



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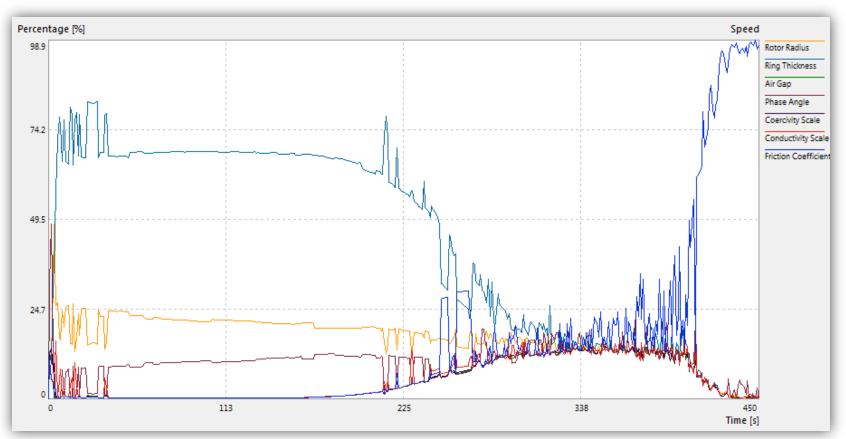
Probabilistic Simulation for Robust Design



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Sensitivity Study for Robust Design

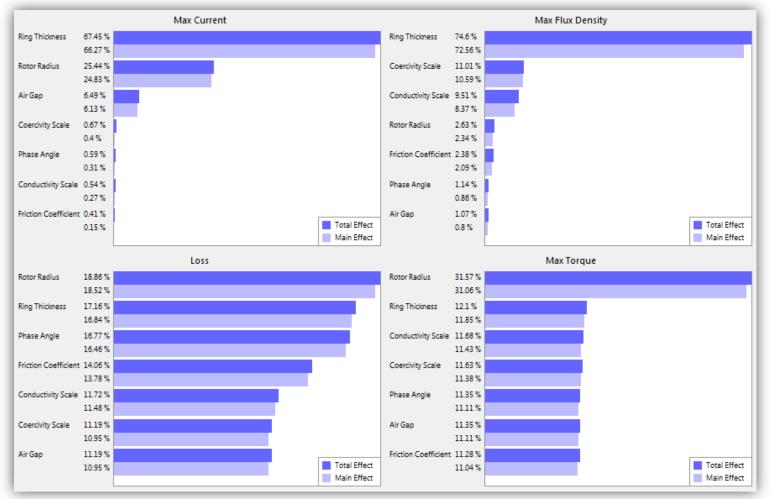


• Ring thickness has most influence on rotor acceleration

• Friction coefficient is the most important factor on constant rotor speed



Sensitivity Study for Robust Design



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Conclusion

Nominal design using classical nominal simulation cannot warranty the reliability and quality of the products, because the nominal parameters are only one fix value.

Robust design is a power-full tool for design of reliable and quality product in the early design stage without any cost. It considers the uncertainty parameters as stochastic distributions.

In the case of the induction motor, the failure probability has been reduced from **52,597% to 0,013%** for the mass manufacturing.

OptiY® is the leading software platform for robust design of all engineering fields using different commercial CAD/CAE-software or in-house codes.