

ANSYS®



ANSYS中国技术大会
中国·上海

ANSYS DesignXplorer 多目标优化技术

- 李少清 / 应用工程师

DesignXplorer简介

DesignXplorer功能特点

基于DX的多目标优化流程

多目标优化案例介绍

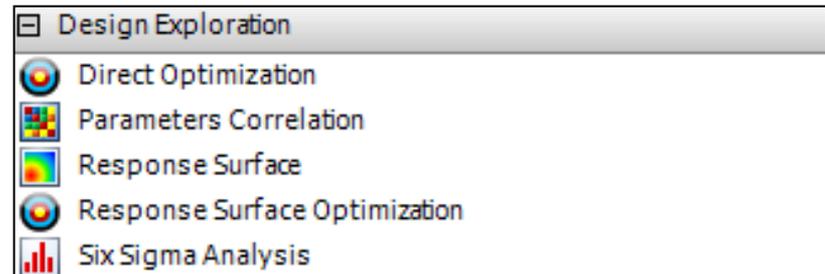
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多目标优化案例介绍

软件背景



- DesignXplorer 是ANSYS公司2001年推出的多目标优化软件，是ANSYS 2000年收购法国参数化技术公司CADOE后，将其技术集成到Workbench中所推出的新模块。
- 多目标参数化设计模块

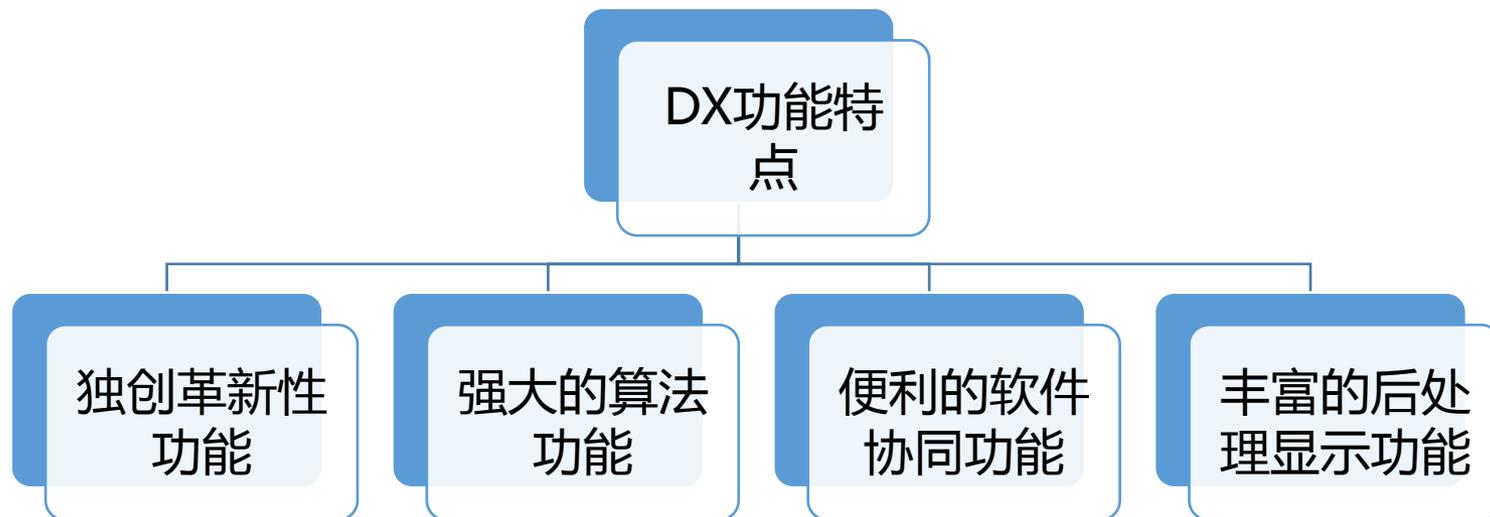
DesignXplorer简介

DesignXplorer功能特点

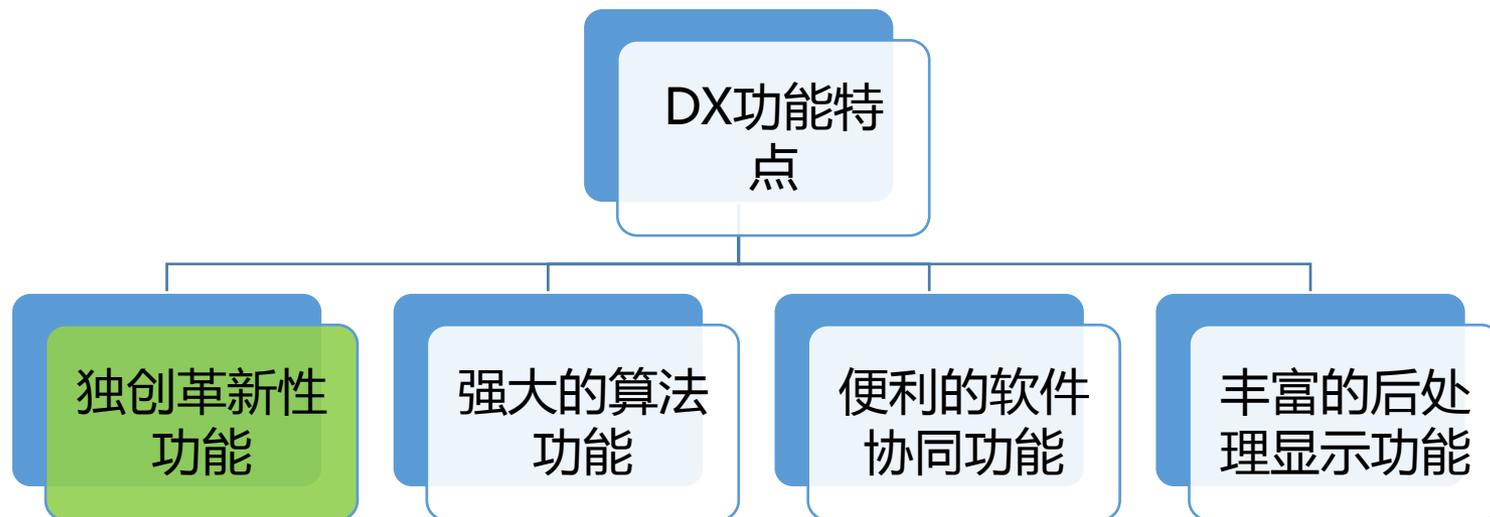
基于DX的多目标优化流程

多目标优化案例介绍

DesignXplorer功能特点



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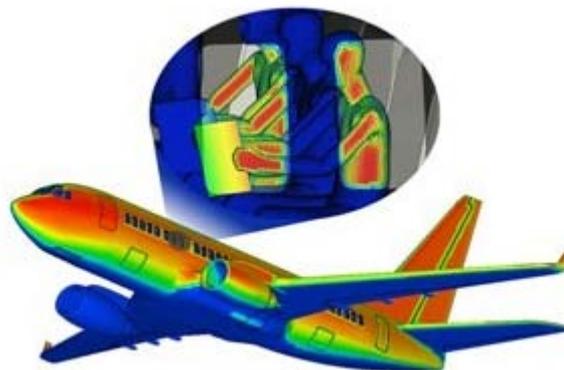
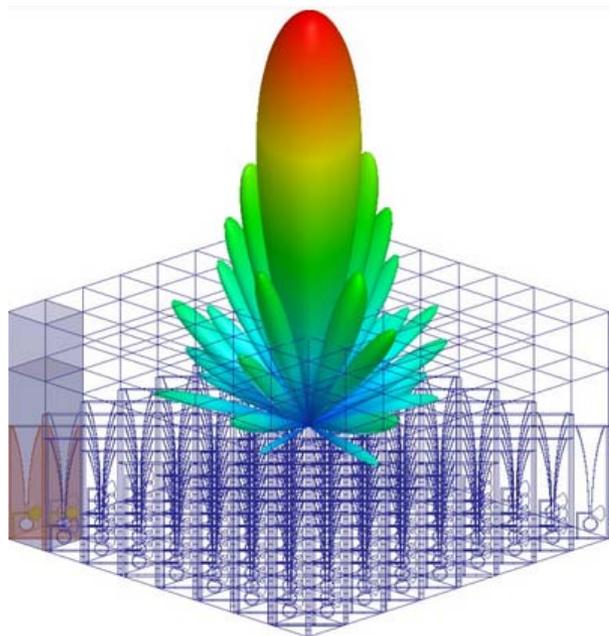
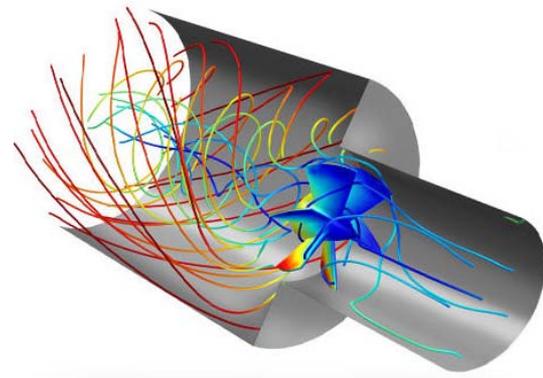
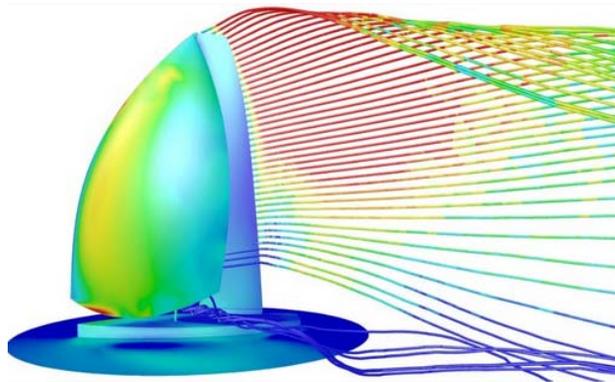
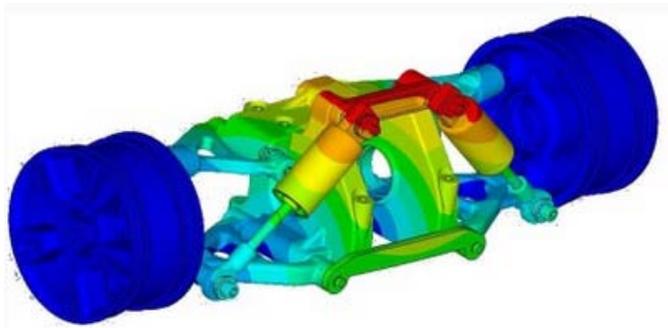
多目标优化



- 传统优化最重要特征：只有一个优化目标。在其它指标满足一定要求前提下，调整优化设计变量，使某一项指标达到最优。
- 实际工程需要多个优化目标，需要产品较好的总体性能，即产品多项指标皆趋向于最好，而不是某项指标达到最好而无视其它需要。因此需要对各项优化指标进行折衷和平衡，以得到最优结果。

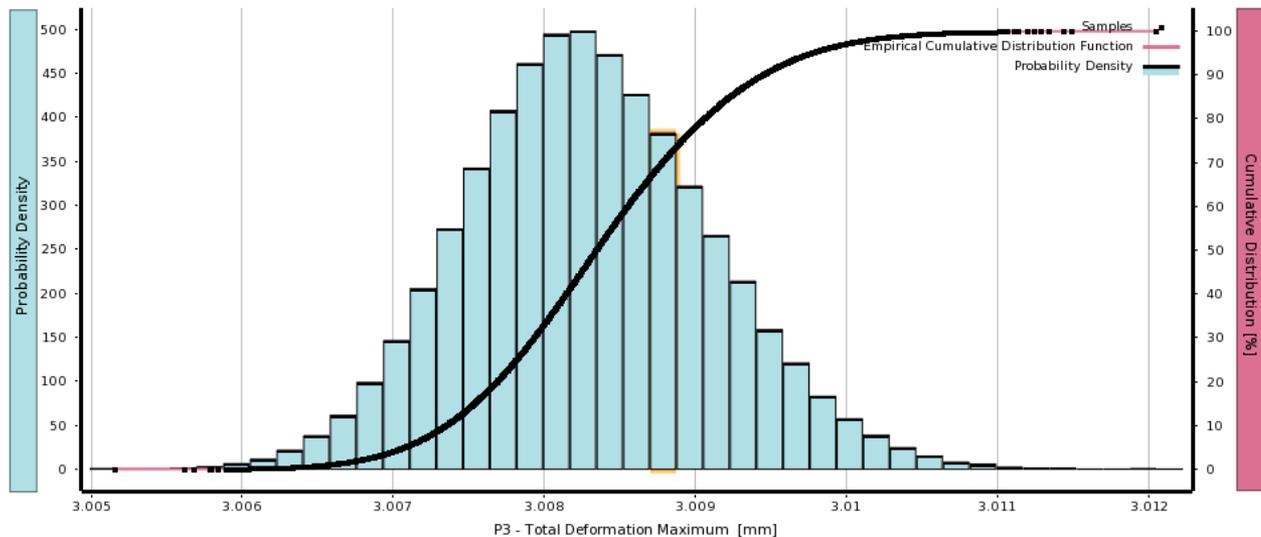
DesignXplorer功能特点

支持Workbench平台下所有物理场优化



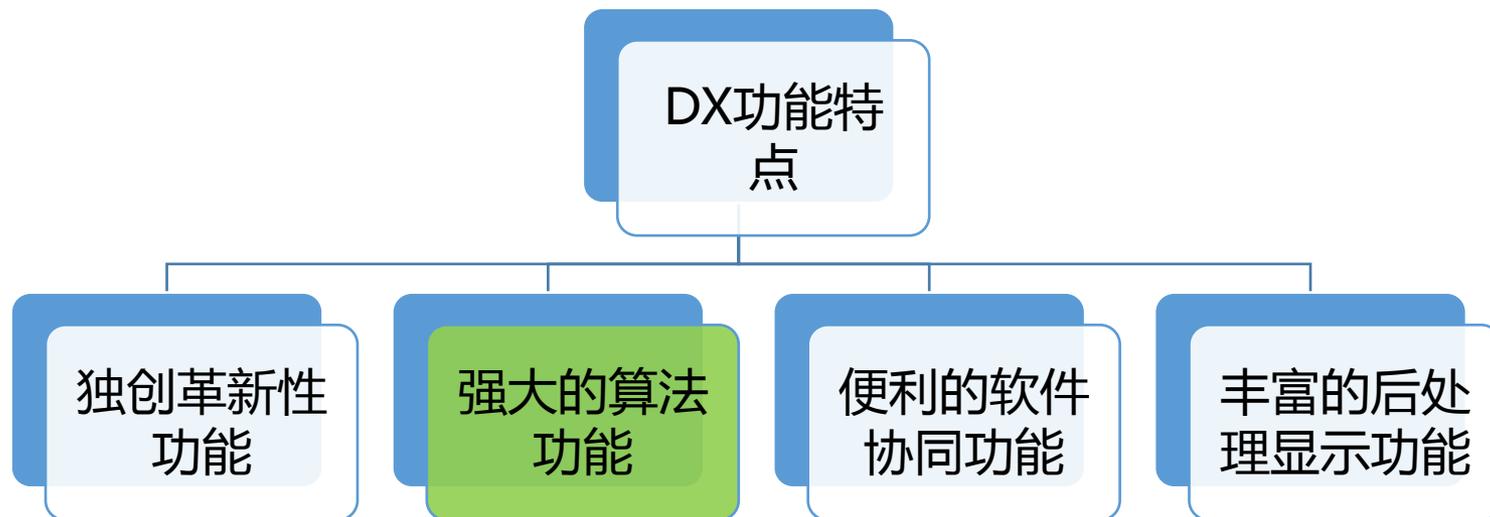
DesignXplorer功能特点

六西格玛设计技术 (DFSS) 和鲁棒设计 (RD)



- 六西格玛设计 (DFSS) 技术——基于六个标准误差理论，假设材料属性、几何尺寸、载荷等不确定性输入变量的概率分布，分析输入变量不确定性对产品性能 (应力、变形等) 的影响，判断产品设计是否达到六西格玛质量标准 (1 , 000 , 000件中只有3.4件失效) ，并评估其可靠概率或失效概率。
- 鲁棒设计 (RD) 技术基于波动性、不确定性假设，综合考虑设计输入变量、不确定输入变量对产品可靠性的影响，对产品进行优化设计，使其达到六西格玛质量标准、减小波动度、优化可靠性等要求。

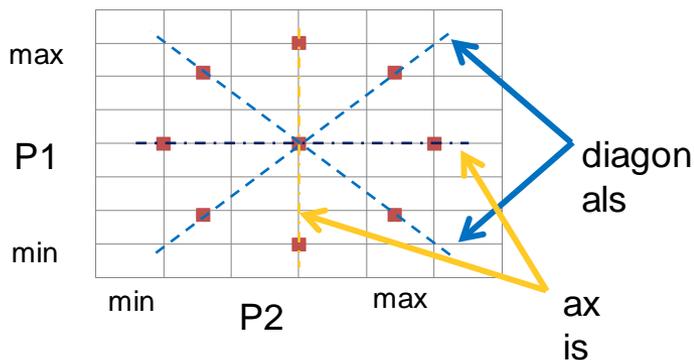
DesignXplorer功能特点



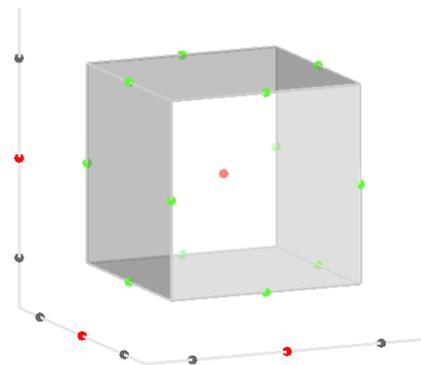
DesignXplorer功能特点

提供多种设计实验 (DOE) 算法

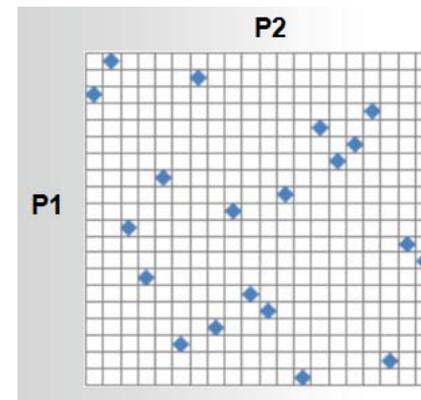
中心复合设计



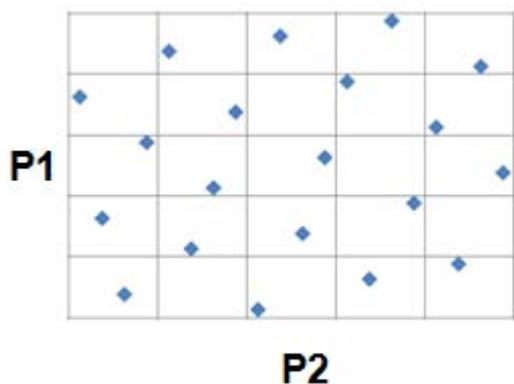
Box-Behnken 设计



拉丁超立方体抽样设计



最优空间填充设计

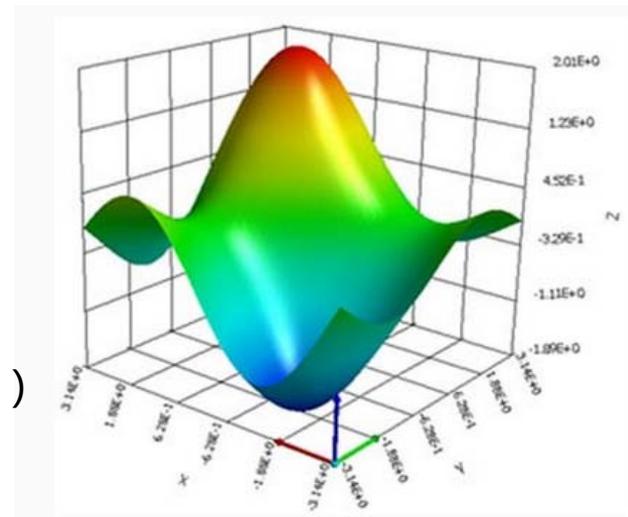


- DOE (Design of Experiment) 是一种安排实验和分析实验数据的数理统计方法，目的是通过对实验进行合理安排，以较小的实验规模，较短的实验周期，以及较低的成本获得理想的实验结果。

提供多种响应面拟合函数和优化算法

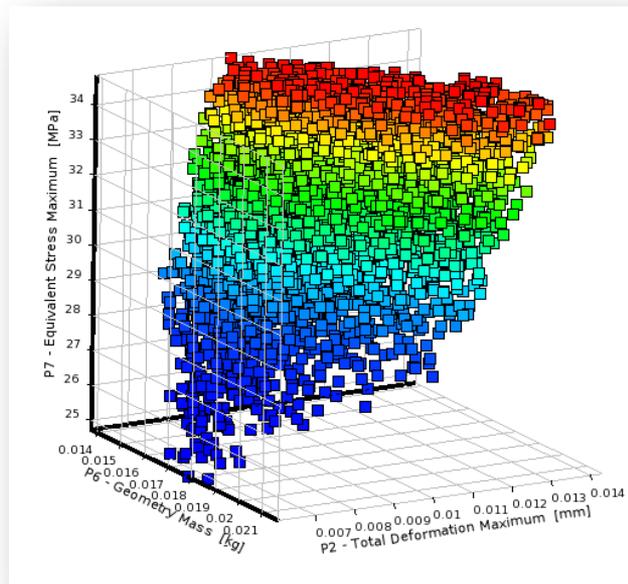
响应面拟合

- 基因聚合法 (Genetic Aggregation)
- 全二阶多项式法
- 克里格法 (Kriging)
- 非参数回归法 (No-Parametric Regression)
- 神经网络法 (Neural Network)
- 稀疏网格法



优化算法

- 筛选优化(Screening Optimization)
- 多目标遗传算法 (MOGA)
- 非线性规划算法 (NLPQL)
- 混合整型序列二次规划算法 (MISQP)
- 自适应单目标优化
- 自适应多目标优化
- 支持外部优化求解器

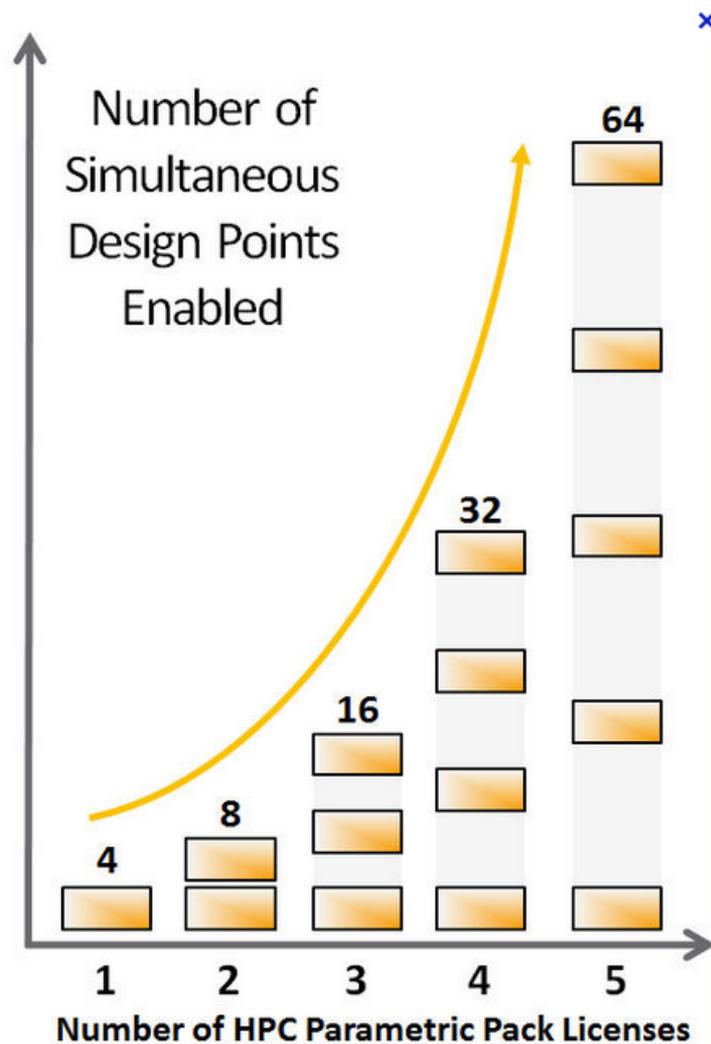


DesignXplorer功能特点

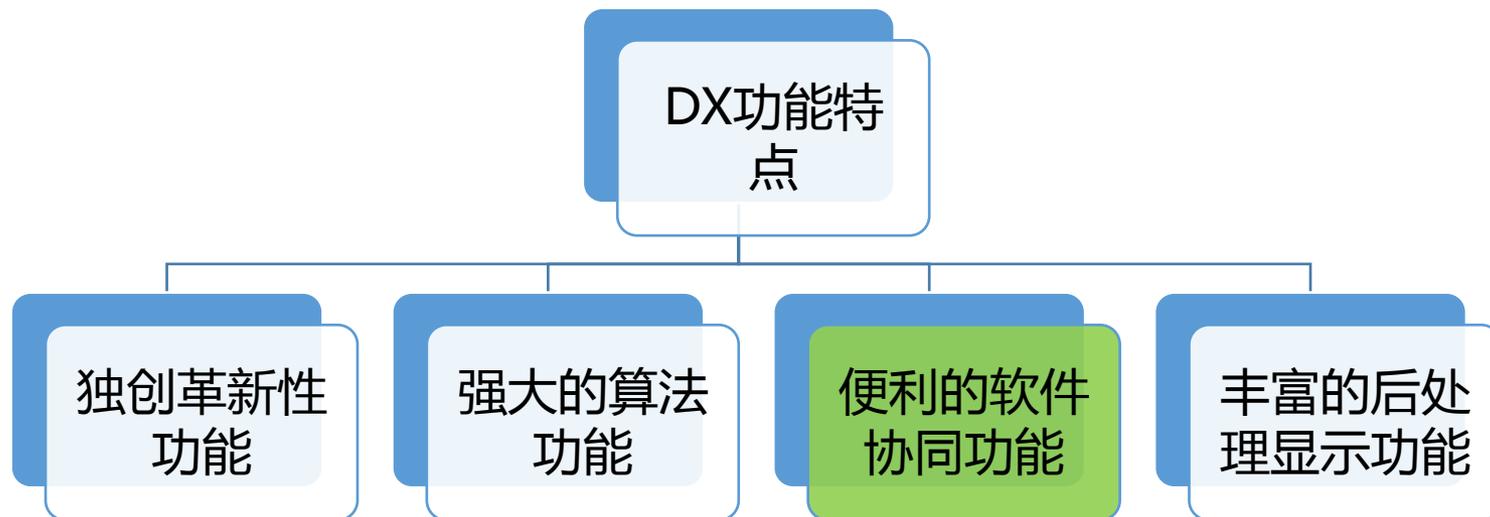
设计点并行求解功能

HPC Parametric Pack Licenses

- 最多可以使用5个HPC Parametric Pack Licenses能够同时对64个设计点进行计算，极大的提高了计算效率，缩短了优化计算的周期。

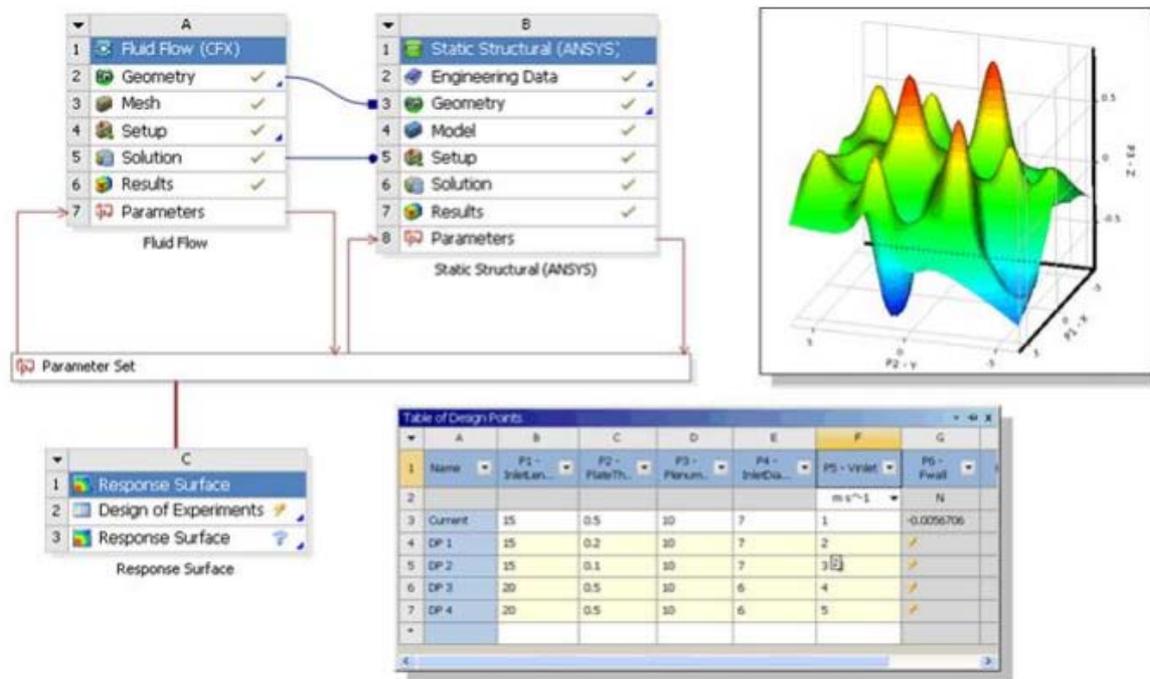


DesignXplorer功能特点



DesignXplorer功能特点

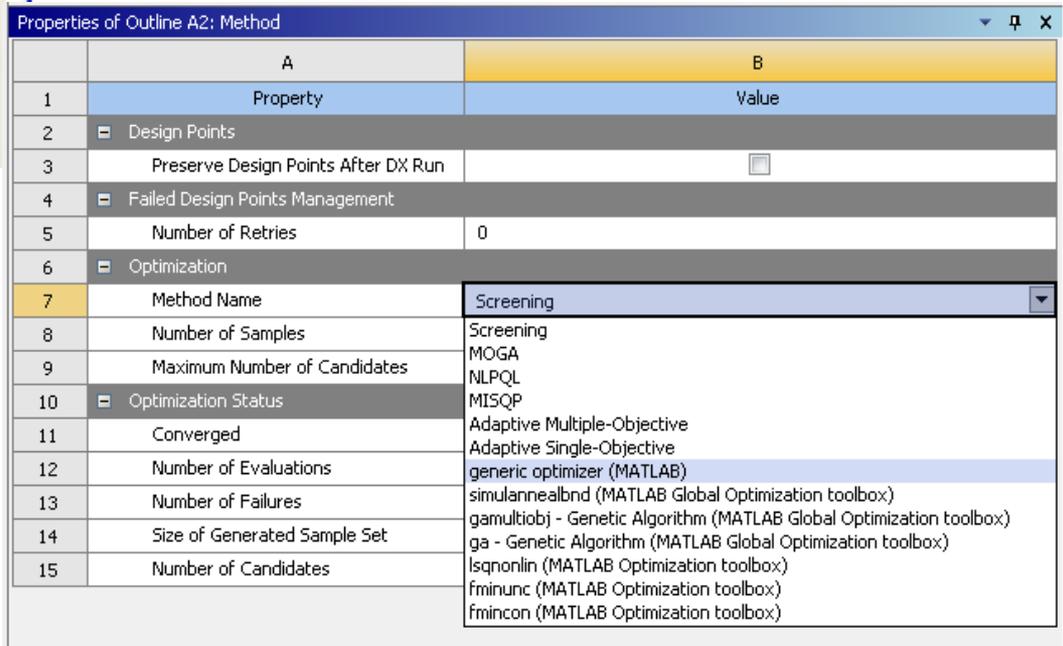
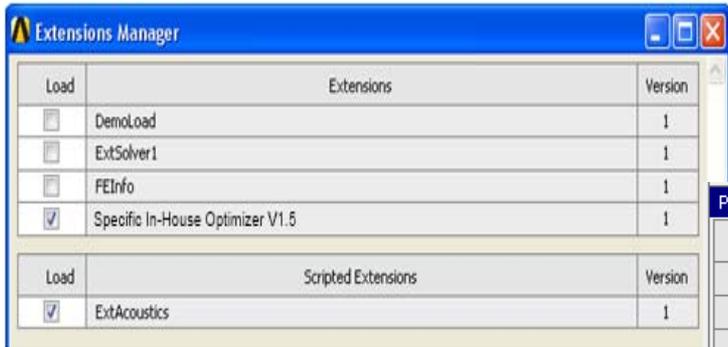
全参数化设计功能



- 支持ANSYS Workbench下的所有计算数据
- 与CAD软件联合进行形状参数优化
- 支持ANSYS参数化设计语言APDL
- 支持其它第三方计算程序（相对于一个独立的优化设计软件）

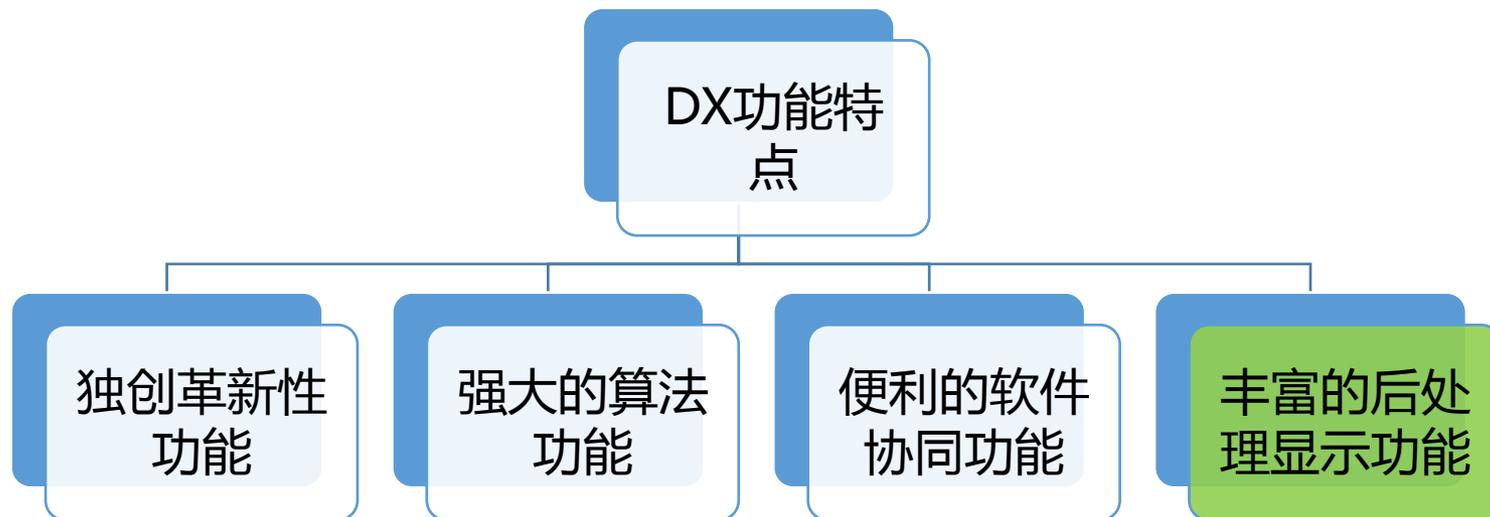
DesignXplorer功能特点

开放式的优化平台



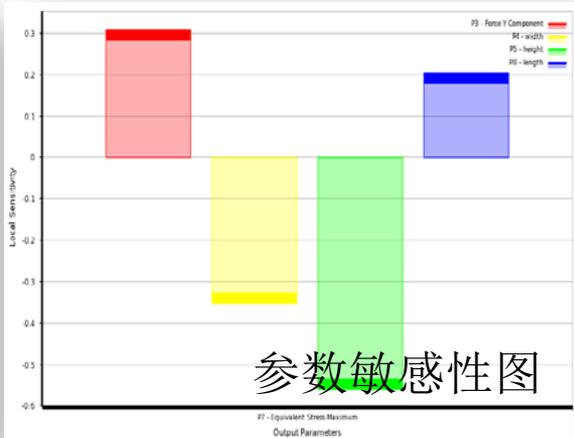
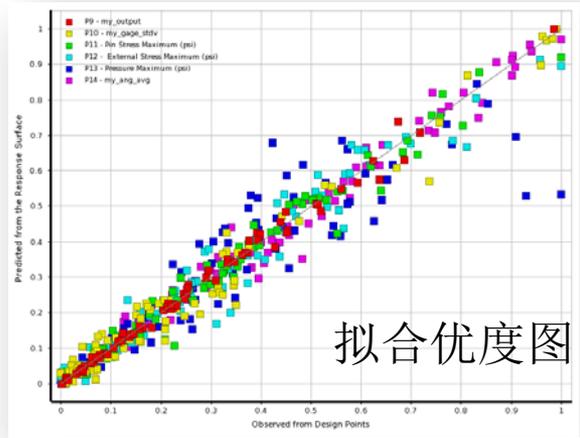
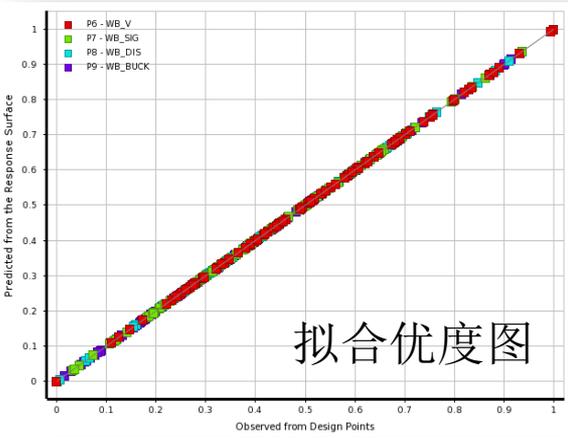
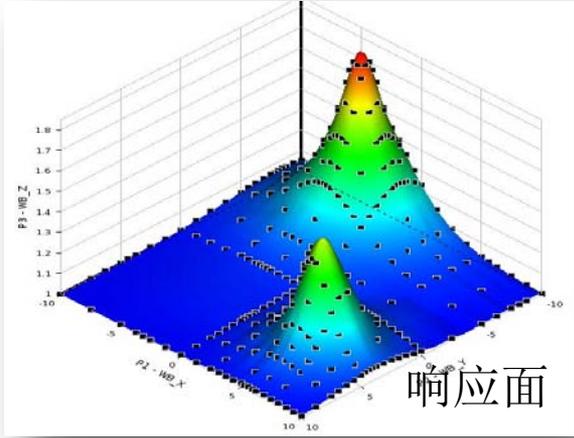
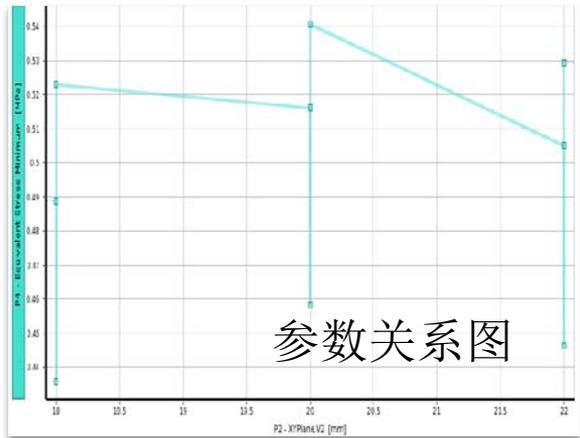
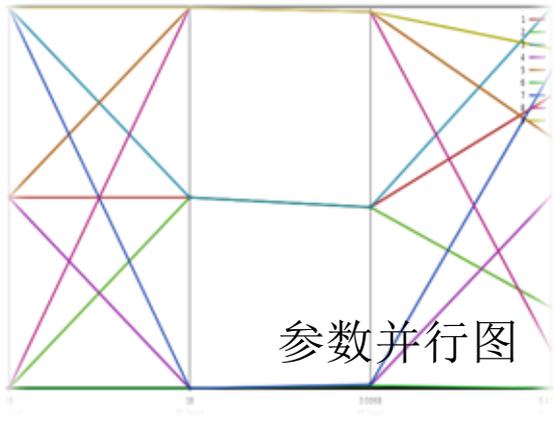
- 支持外部优化工具
- 外部工具通过ACT插件调动
- 可调用用户编写的优化程序
- 可通过ACT调用外部软件进行优化（如matlab）

DesignXplorer功能特点



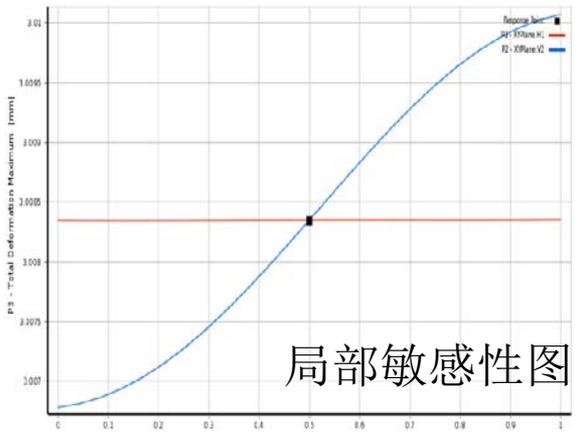
DesignXplorer功能特点

多样化的结果显示工具

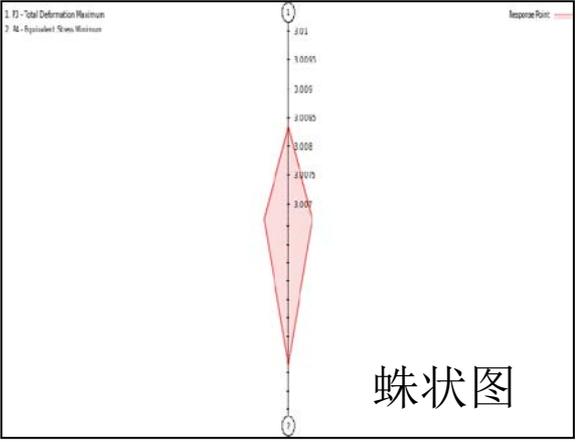


DesignXplorer功能特点

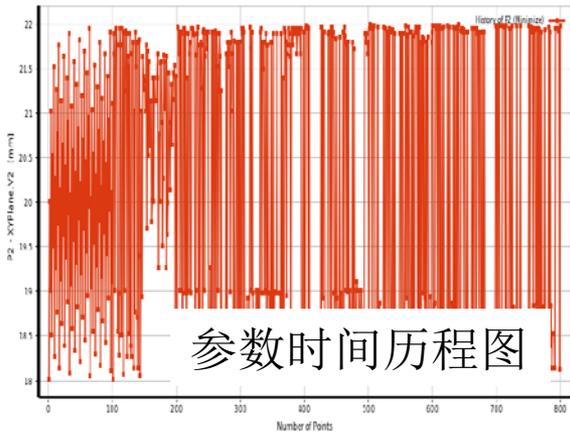
多样化的结果显示工具



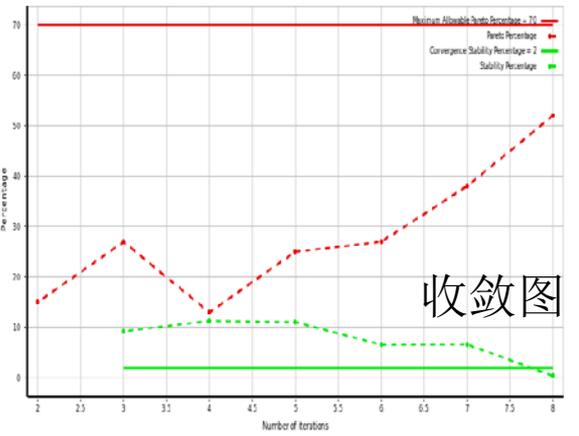
局部敏感性图



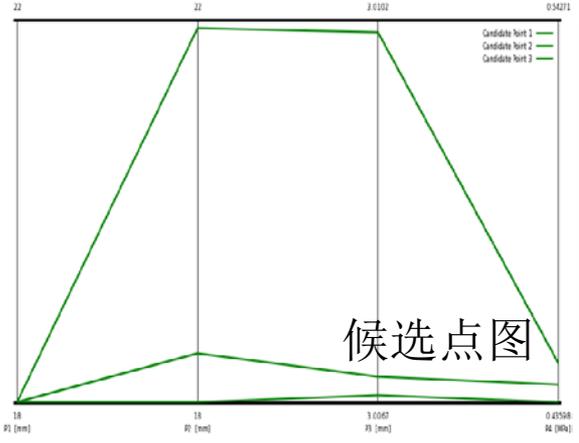
蛛状图



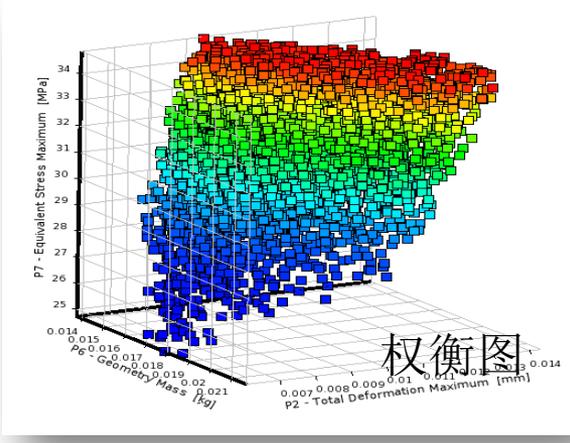
参数时间历程图



收敛图



候选点图



权衡图

DesignXplorer功能特点

多样化的结果显示工具

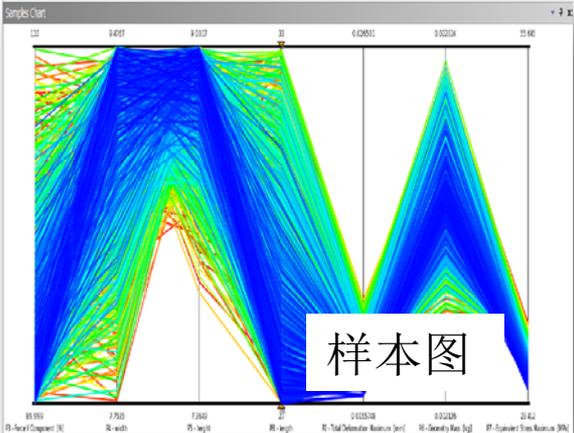
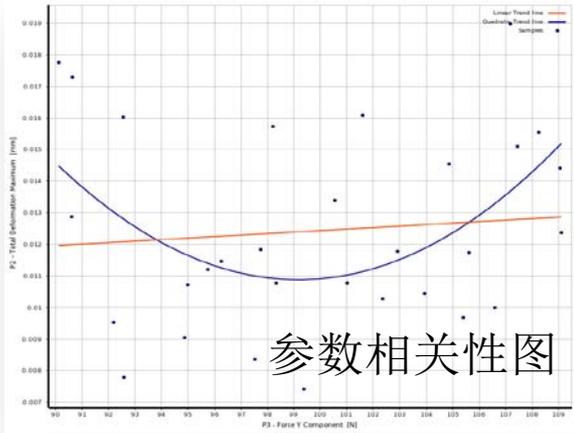
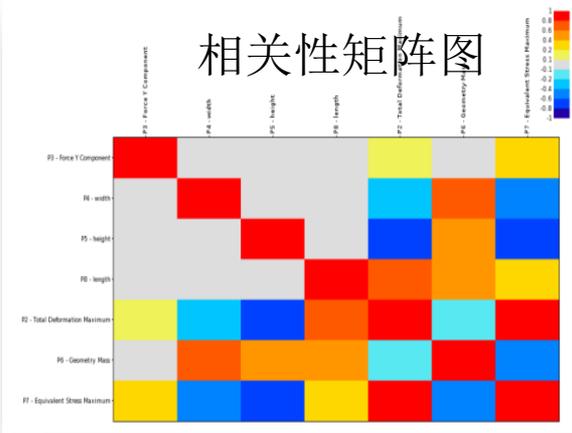


Table of Schematic C4: Six Sigma Analysis

	A	B	C
1	P1 - DI LENGTH	Probability	Sigma Level
2	43.97	0.0069075	-2.462
3	44.8	0.022959	-1.998
4	45.631	0.043931	-1.7068
5	46.461	0.077687	-1.4208
6	47.292	0.13922	-1.0838
7	48.122	0.2242	-0.7581
8	48.952	0.33453	-0.42881
9	49.783	0.46503	-0.087763
10	50.613	0.59305	0.23617
11	51.443	0.71737	0.57505
12	52.274	0.81438	0.89414
13	53.104	0.89377	1.2468
14	53.934	0.94438	1.5909
15	54.765	0.96858	1.8604
16	55.595	0.98111	2.0771
17	56.425	0.98845	2.2717
18	57.256	0.99309	2.462
*	New Parameter Value		

DFSS 分析结果概率表

Table of Schematic C2: Optimization

	A	B	C	D
1	Optimization Study			
2	Seek P1 = 200 Hz	Goal, Seek P1 = (Default Importance)		
3	Optimization Method			
4	Adaptive Single-Objective	The Adaptive Single-Objective method is a gradient-based algorithm to provide a refined, global optimization result. It supports a single objective, multiple constraints and aims at finding the global optimum. It is limited to continuous input parameters.		
5	Configuration	Find 3 candidates in a maximum of 40 evaluations and 20 domain reductions.		
6	Status	Not Converged because the Maximum Number of Evaluation is reached.		
7	Candidate Points			
8		Candidate Point 1 (DP 55)	Candidate Point 2 (DP 81)	Candidate Point 3 (DP 100)
9	P2 - ds_web	16.901	17.016	17.7
10	P6 - CylinderExtrude_Half (mm)	75.31	76.524	83.057
11	P1 - 1st Frequency Mode In Range Frequency (Hz)	★ 200	★ 199.99	★ 200.03

多目标优化的输出

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基于DX的多目标优化流程

多目标优化案例介绍

基于DX的多目标优化流程

What if ?

参数化计算系统

相关性 | 敏感性

DX优化模块

DOE

响应面

What if?

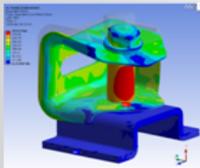
Parameters coming from any source

CAD



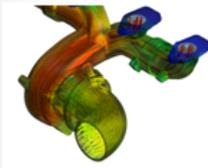
DesignModeler
SpaceClaim
Catia V5
UG NX
SolidWorks
Creo Parametric
Solid Edge
Autodesk Inventor
...

Structural



Engineering data
Meshing
Mechanical
Mechanical APDL
ExplicitSTR
Vista TF, CCD...
Icepak
nCode
...

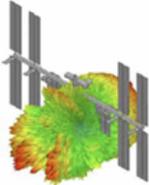
CFD



CFX
Fluent
CFD Post
Polyflow
AQWA
ICEM CFD

And also for some custom usages:
Excel, External Connection

Electromagnetics



Ansoft Products:
Designer
HFSS
Maxwell
Q3D Extractor
Simplorer

优化目标 | 约束条件

执行优化

基于DX的多目标优化流程

What if ?

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响应面

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执行优化

The screenshot displays the ANSYS interface with three main components:

- Simulation Setups:** Two panels, A (Fluid Flow (CFX)) and B (Static Structural (ANSYS)), showing hierarchical tree views of the simulation process including Geometry, Mesh, Setup, Solution, Results, and Parameters.
- 3D Surface Plot:** A 3D plot showing a multi-peaked surface with a color gradient from blue (low) to red (high).
- Design Points Table:** A table titled 'of Design Points' with columns A through G. The data is as follows:

Name	A	B	C	D	E	F	G
Current	35	0.5	30	7	1		
DP 1	25	0.2	30	7	2		
DP 2	35	0.1	30	7	3		
DP 3	20	0.5	30	6	4		
DP 4	20	0.5	30	6	5		
- Details of Sketch1:** A panel showing sketch properties. Under 'Dimensions: 2', two dimensions are listed:

Dimension	Value
D H1	20 mm
D V2	20 mm

基于DX的多目标优化流程

What if ?

参数化计算系统

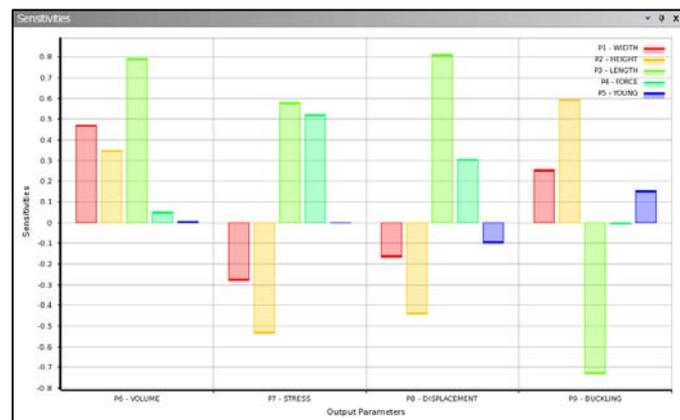
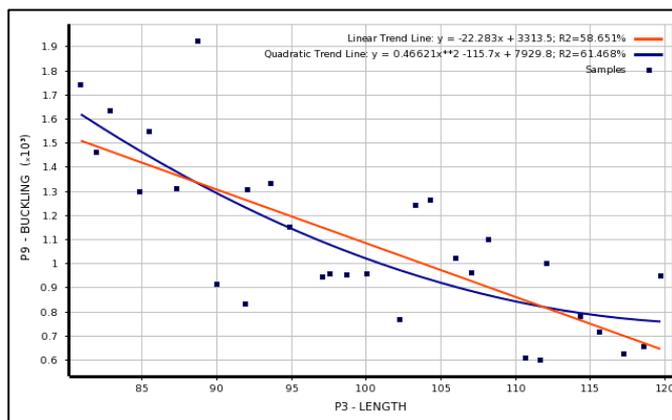
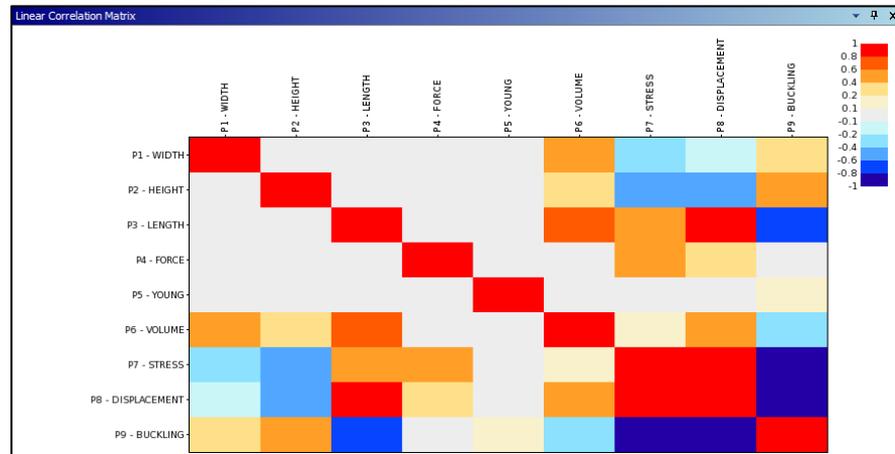
相关性 | 敏感性

DX优化模块

DOE

响应面

	Charts
12	
13	✓ Correlation Matrix
14	✓ Sensitivities
15	✓ Determination Histogram
16	✓ Determination Matrix
17	✓ Correlation Scatter



优化目标 | 约束条件

执行优化

基于DX的多目标优化流程

- Design Exploration
 - Direct Optimization
 - Parameters Correlation
 - Response Surface
 - Response Surface Optimization
 - Six Sigma Analysis

What if ?

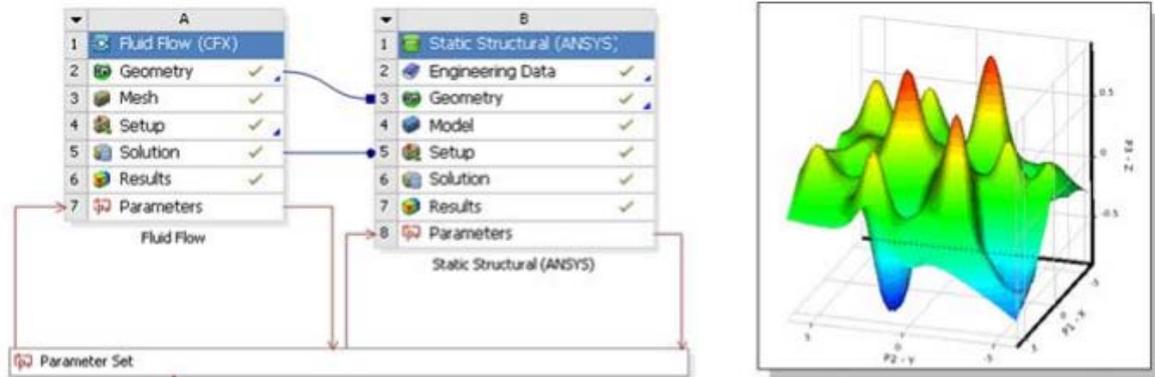
参数化计算系统

相关性 | 敏感性

DX优化模块

DOE

响应面



Response Surface Optimization

Name	F1 - Inlet...	F2 - PlateTh...	F3 - Press...	F4 - InletD...	F5 - Visc...	F6 - m...
Current	35	0.5	30	7	1	
SP 1	35	0.2	30	7	2	
SP 2	35	0.1	30	7	3	
SP 3	20	0.5	30	6	4	
SP 4	20	0.5	30	6	5	

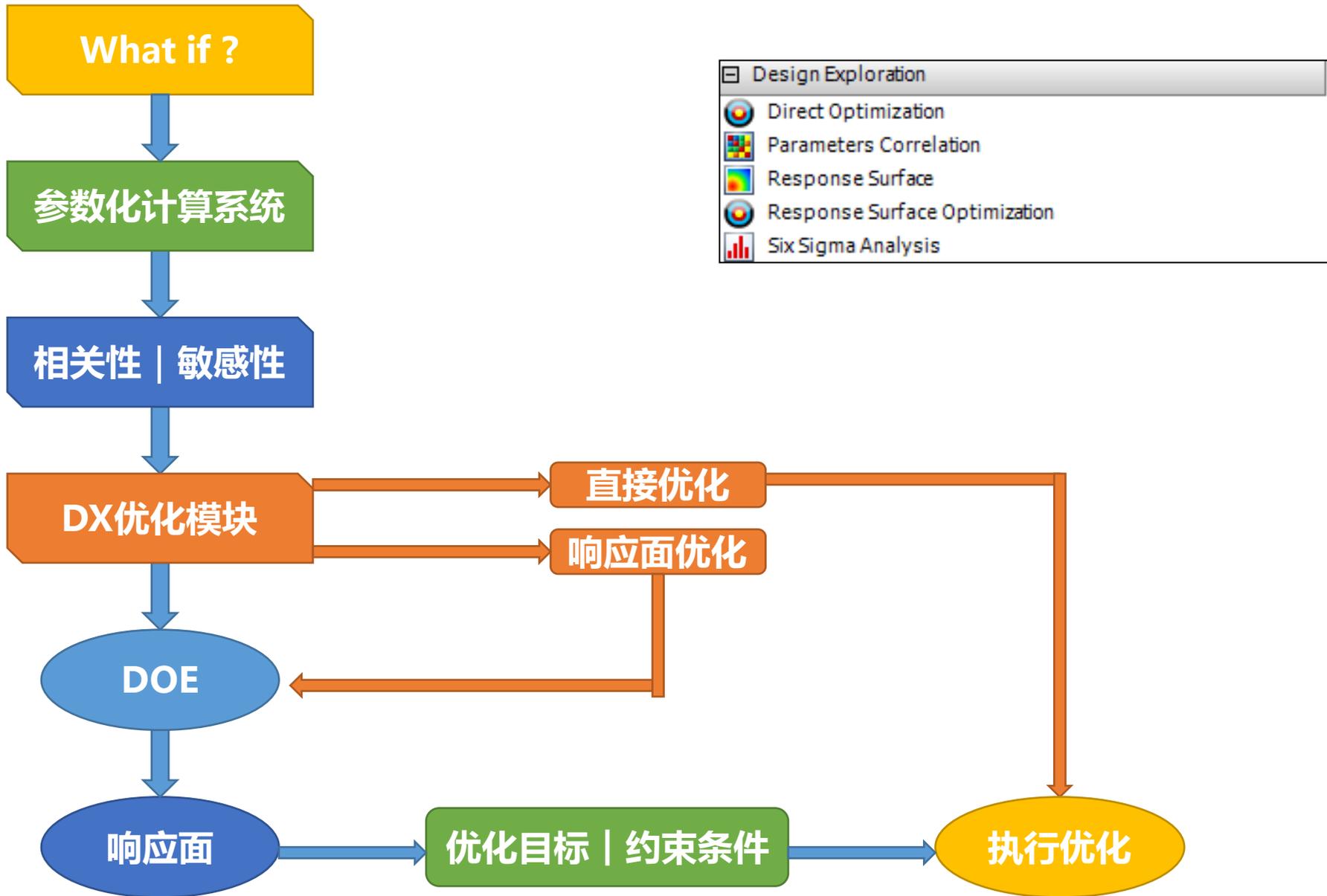
Details of Sketch1

Sketch	Sketch1
Sketch Visibility	Show Sketch
Show Constraints?	No
Dimensions: 2	
D H1	20 mm
D V2	20 mm
Edges: 4	
Line	Ln7
Line	Ln8
Line	Ln9
Line	Ln10

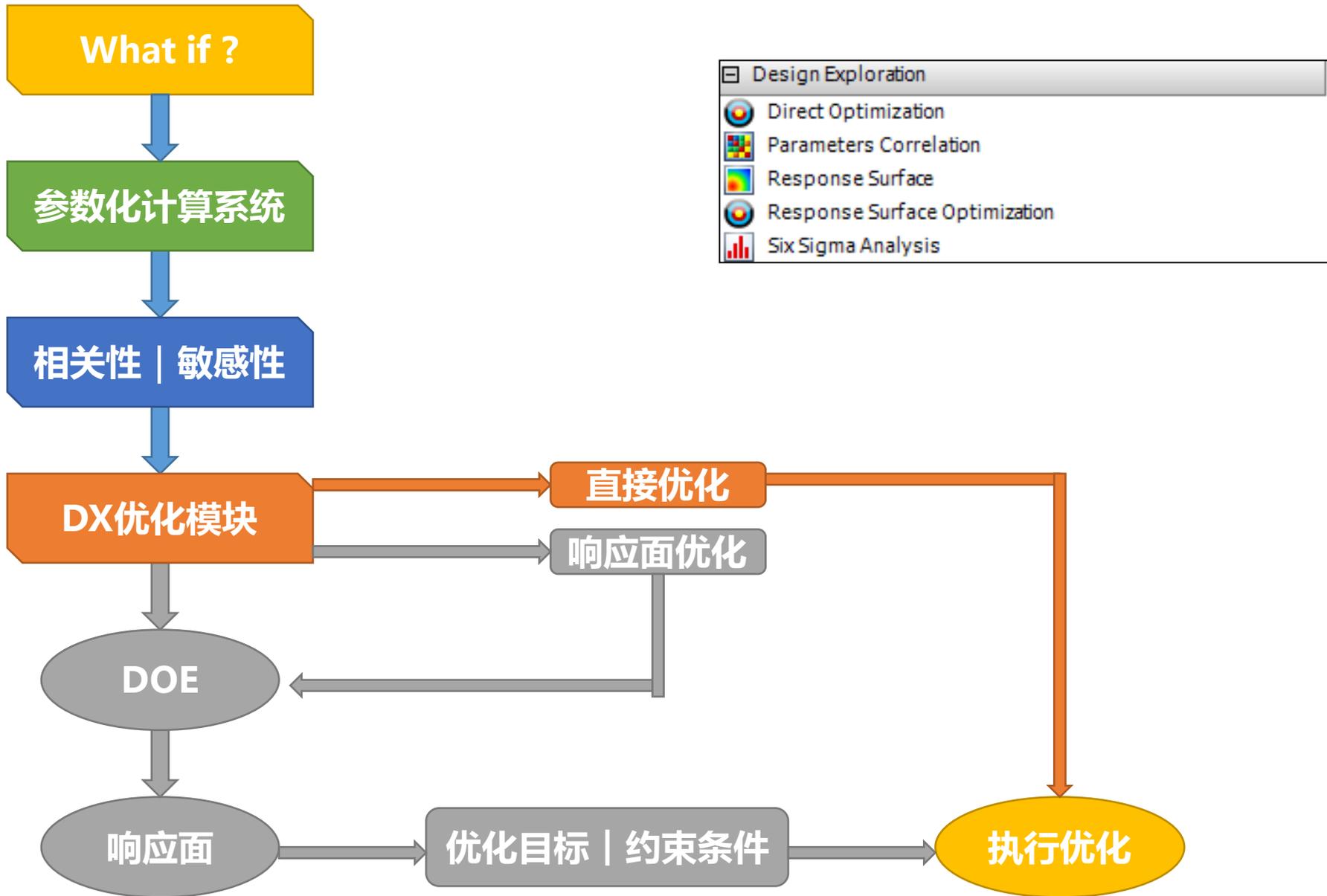
优化目标 | 约束条件

执行优化

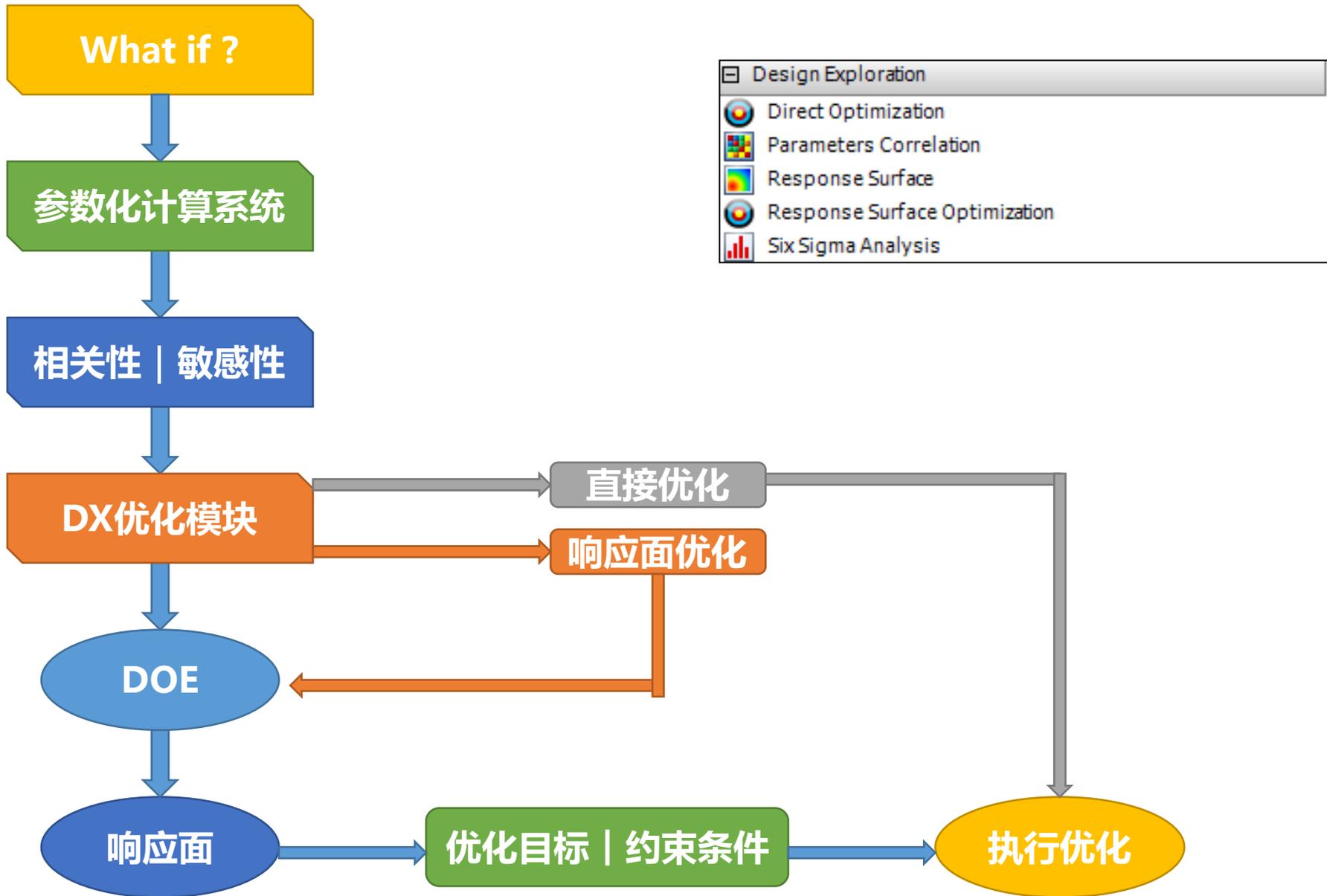
基于DX的多目标优化流程



基于DX的多目标优化流程



基于DX的多目标优化流程



基于DX的多目标优化流程

What if ?

参数化计算系统

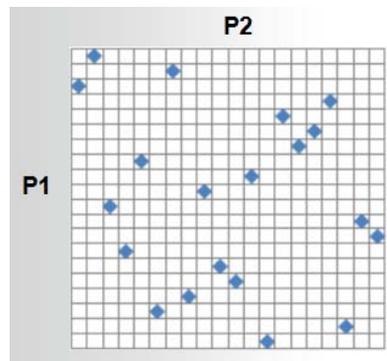
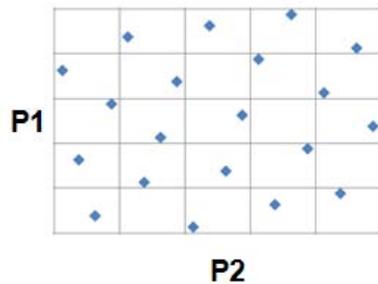
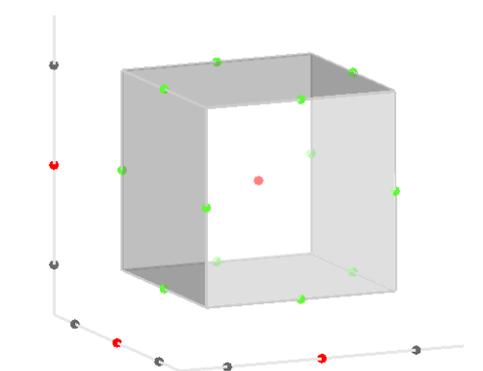
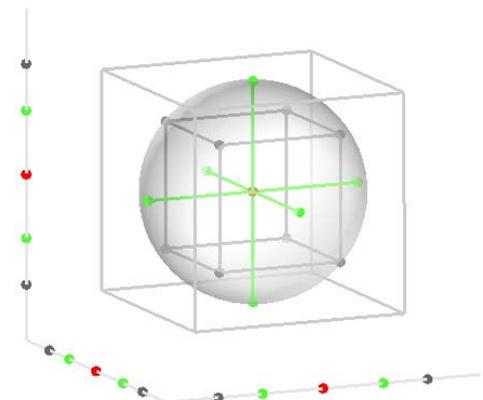
相关性 | 敏感性

DX优化模块

DOE

响应面

- 中心复合设计 (CCD)
- Box-Behnken设计(BBD)
- 拉丁超立方体抽样设计 (LSH)
- 最优空间填充设计 (OSF)
- 稀疏网格初始化
- 外部设计实验
- 用户自定义/自定义+抽样



优化目标 | 约束条件

执行优化

基于DX的多目标优化流程

What if ?

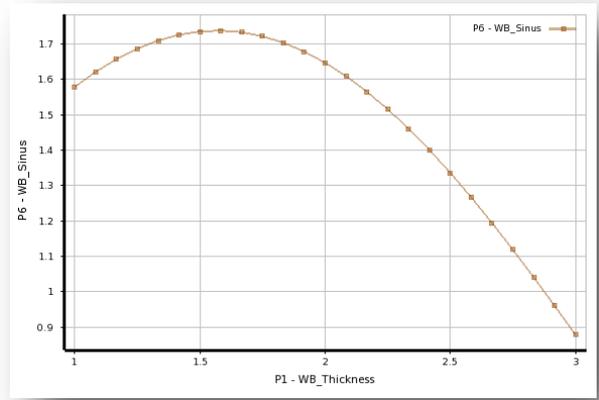
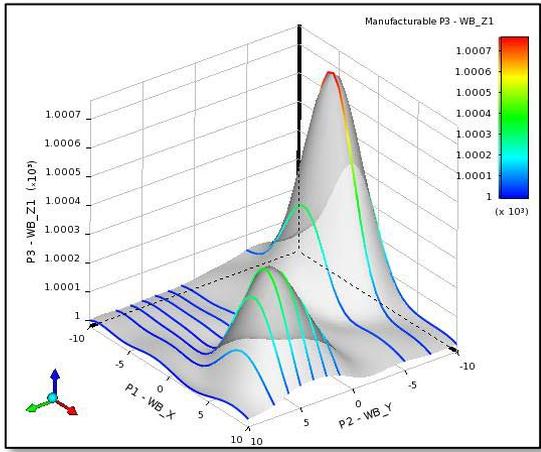
参数化计算系统

相关性 | 敏感性

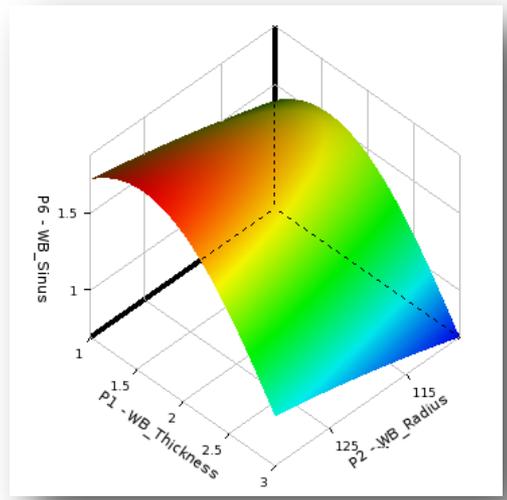
DX优化模块

DOE

响应面



- 基因聚合法 (Genetic Aggregation)
- 全二阶多项式法
- 克里格法 (Kriging)
- 非参数回归法 (No-Parametric Regression)
- 神经网络法 (Neural Network)
- 稀疏网格法



优化目标 | 约束条件

执行优化

基于DX的多目标优化流程

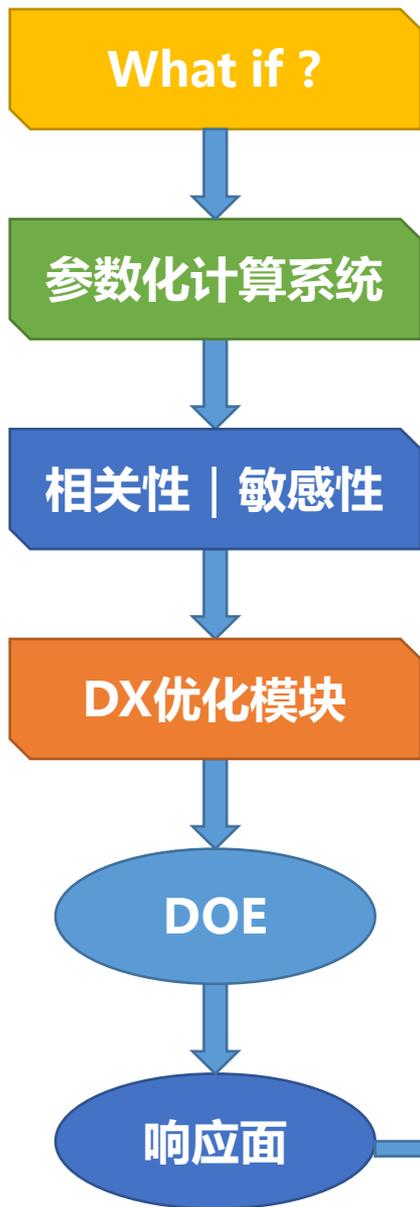
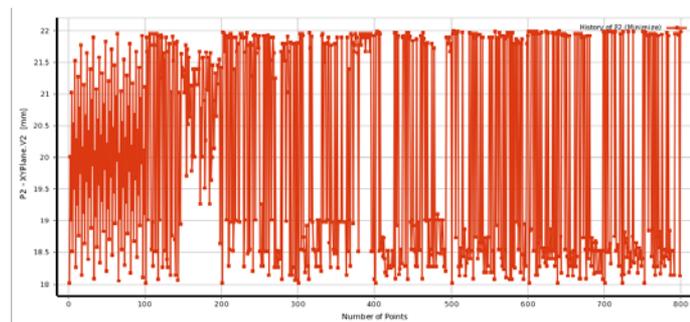


Table of Schematic D4: Optimization

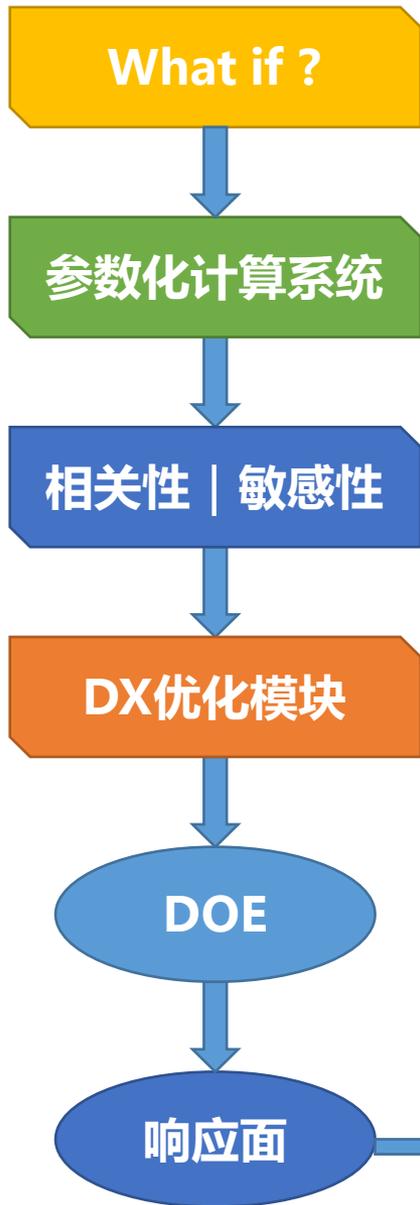
1	A	B	C		D	E	F	G
	Name	Parameter	Type	Target	Type	Lower Bound	Upper Bound	
3	Minimize P1	P1 - XYPlane.H1	Minimize		No Constraint			
4	Minimize P2	P2 - XYPlane.V2	Minimize		No Constraint			
5	Minimize P4; P4 <= 350 MPa	P4 - Equivalent Stress Minimum	Minimize		Values <= Upper Bound		350	
6	Maximize P3; P3 <= 50 mm	P3 - Total Deformation Maximum	Maximize		Values <= Upper Bound		50	
*								

	Enabled	Monitoring
Optimization	<input checked="" type="checkbox"/>	
Objectives and Constraints		
Minimize P1		
Minimize P2		
Minimize P4; P4 <= 350 MPa		
Maximize P3; P3 <= 50 mm		
Domain		
Geometry (A1)		
P1 - XYPlane.H1	<input checked="" type="checkbox"/>	
P2 - XYPlane.V2	<input checked="" type="checkbox"/>	

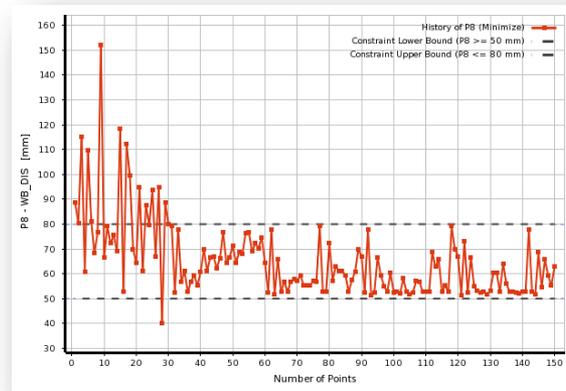
- 输入参数取值范围
- 设置优化目标取值范围



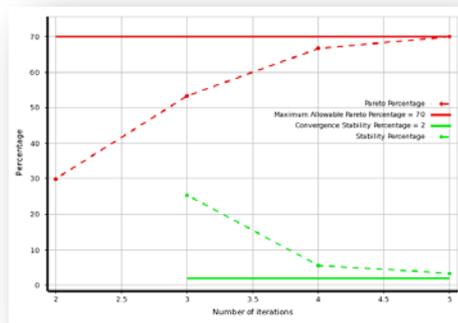
基于DX的多目标优化流程



	Enabled	Monitoring
Optimization		
Objectives and Constraints		
Minimize P7		
Minimize P8; 50 mm <= P8 <= 80 mm		
Seek P6 = 950 mm^3		
Domain		
Microsoft Office Excel (A1)		
P1 - WB_B	<input checked="" type="checkbox"/>	
P2 - WB_D	<input checked="" type="checkbox"/>	
P3 - WB_L	<input checked="" type="checkbox"/>	
P4 - WB_P	<input checked="" type="checkbox"/>	
P5 - WB_E	<input checked="" type="checkbox"/>	
Parameter Relationships		
Convergence Criteria	<input checked="" type="checkbox"/>	



- 筛选优化(Screening Optimization)
- 多目标遗传算法 (MOGA)
- 非线性规划算法 (NLPQL)
- 混合整型序列二次规划算法 (MISQP)
- 自适应单目标优化
- 自适应多目标优化
- 支持外部优化求解器



优化目标 | 约束条件

执行优化

DesignXplorer简介

DesignXplorer功能特点

基于DX的多目标优化流程

多目标优化案例介绍

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感谢聆听