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基于modeFRONTIER平台的多学科优化在车身轻量化上的应用

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研究背景

2003-2013 汽车重量对比

Vehicle Weight: 10 Year Comparison

(James Holland, Weijian Han, Matthew Zaluzec, 2013)

研究背景

2007 2014 2020 2030

Weight Reduction of (100 - 350 kg)

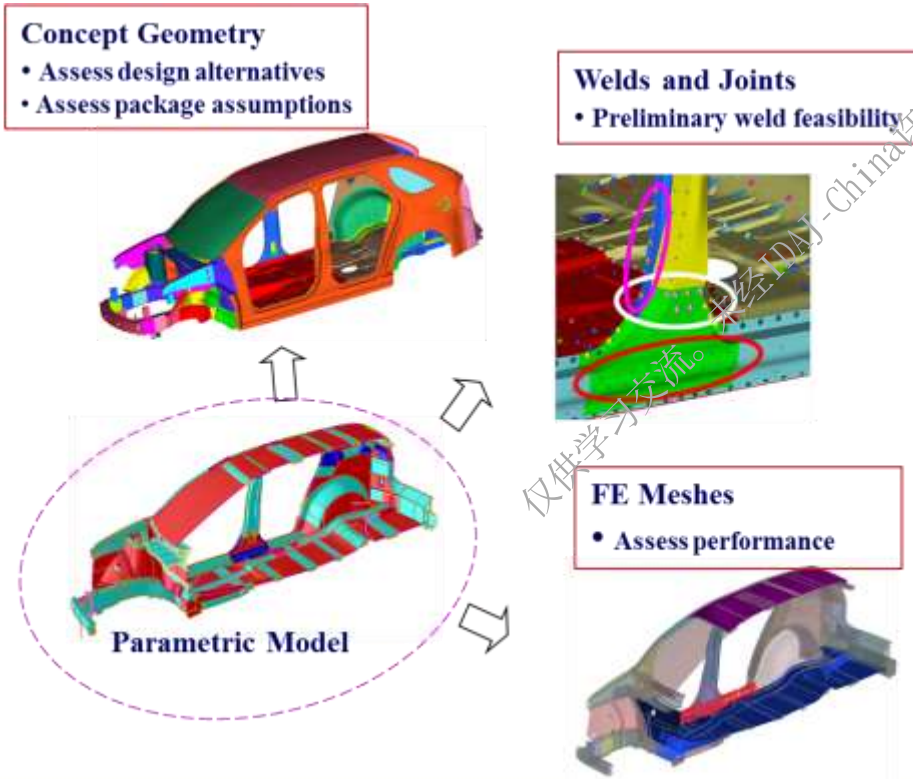
Mid Term

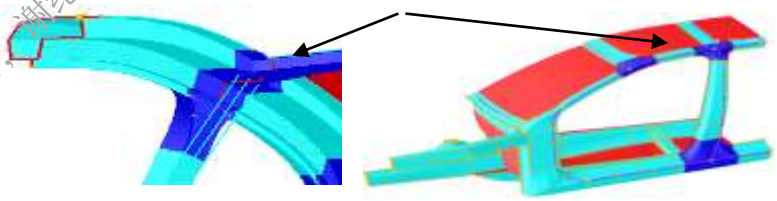
- Smaller displacement engines
- Lightweight materials
- Smaller components

研究背景

参数优化

Define the desired changes of geometry, sections and locations, into a set of controllable parameters for efficient model generation and evaluation.





Parametric modeling brings topology optimization result to design reality. But, it involves manual design iterations to achieve individual attribute performance.

(R. Yang, 2011)

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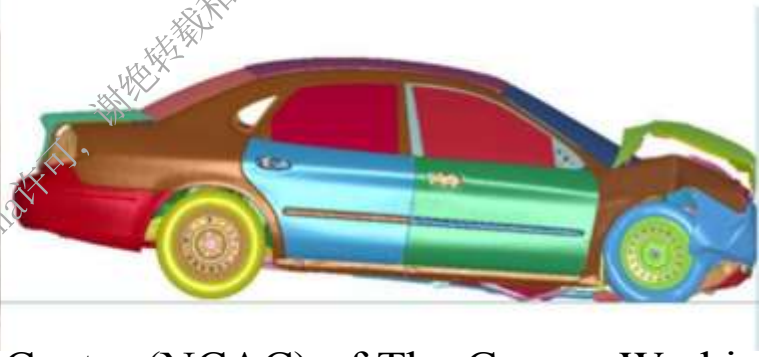
优化实例

模型简介

2001 Ford Taurus model from National Crash Analysis Center (NCAC) for Frontal Impact



Developed at the National Crash Analysis Center (NCAC) of The George Washington University (GWU) under contract with the Federal Highway Administration (FHWA) for studying and advancing vehicle and highway safety research.

轻量化设计的同时，满足设定的耐撞性要求。即要求保证碰撞性能不因减重恶化，甚至要求耐撞性能有一定的提高。

NCAC, Development and Validation of a Finite Element Model for a 2001 Ford Taurus Passenger Sedan NCAC 2008-T-005, prepared for FHWA, Dec 2008.

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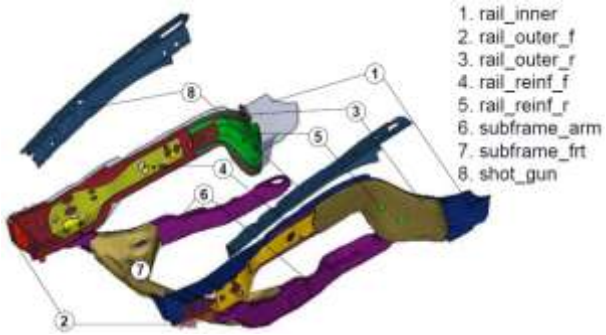
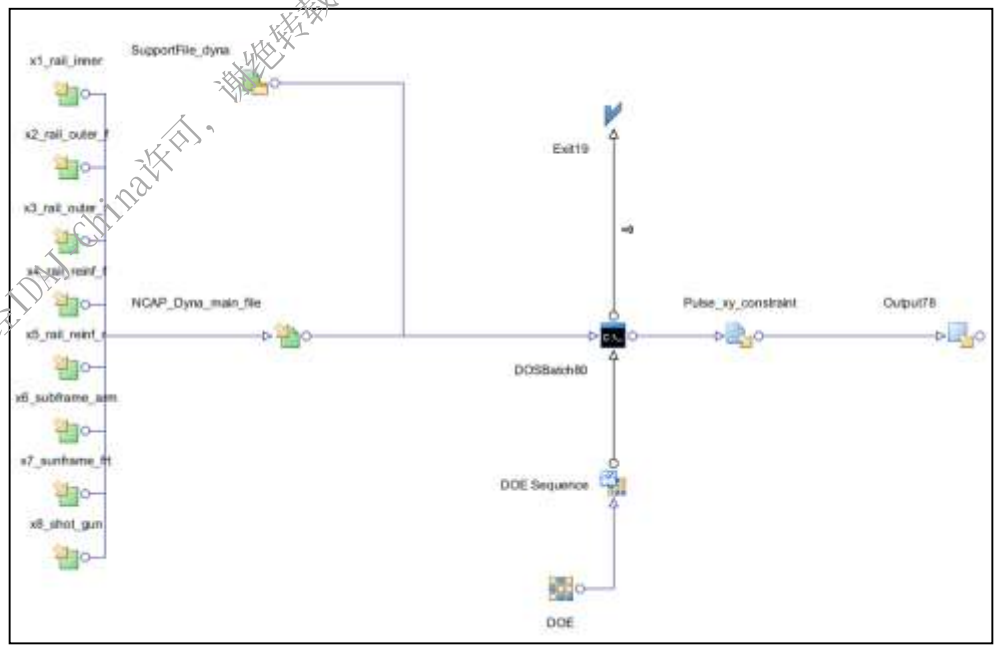
优化实例

集成DOS的数据获取



DVs	Description	Range	Baseline	Std.
x1	rail_inner	[1.50,2.30]	1.90	0.05
x2	rail_outer_front	[1.50,2.30]	1.91	0.05
x3	rail_outer_rear	[2.00,3.00]	2.51	0.06
x4	rail_reinf_front	[1.90,2.90]	2.40	0.06
x5	rail_reinf_rear	[2.00,3.10]	2.55	0.06
x6	rail_reinf_rear	[1.80,2.70]	2.55	0.06
x7	subframe_front	[1.80,2.70]	2.25	0.06
x8	shot_gun	[1.20,1.80]	1.50	0.03



Zhan Z, Fu Y, Yang R J. A Stochastic Bias Corrected Response Surface Method and its Application to Reliability-Based Design Optimization[J]. SAE International Journal of Material and Manufacturing, 2014, 7(2):262-268.

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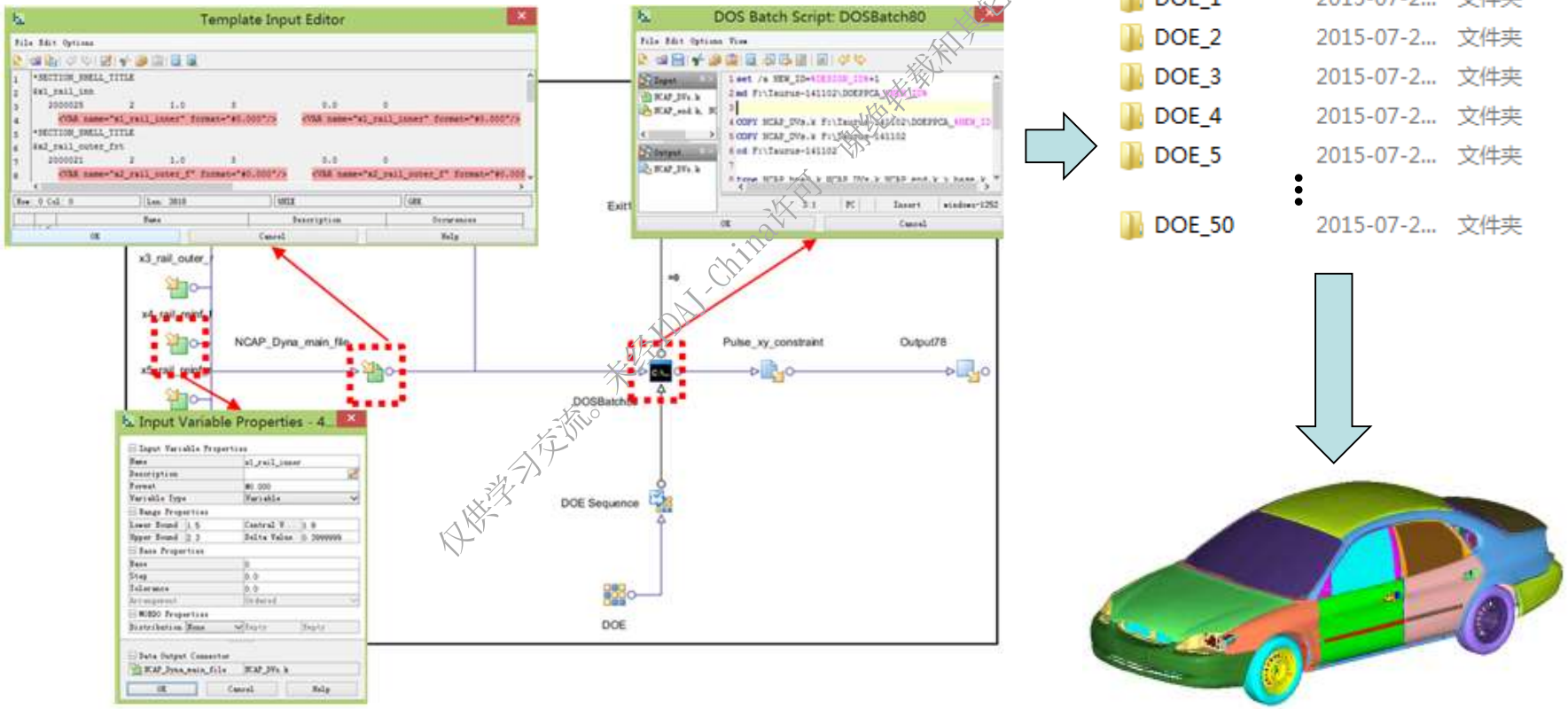
优化实例

集成DOS的数据获取

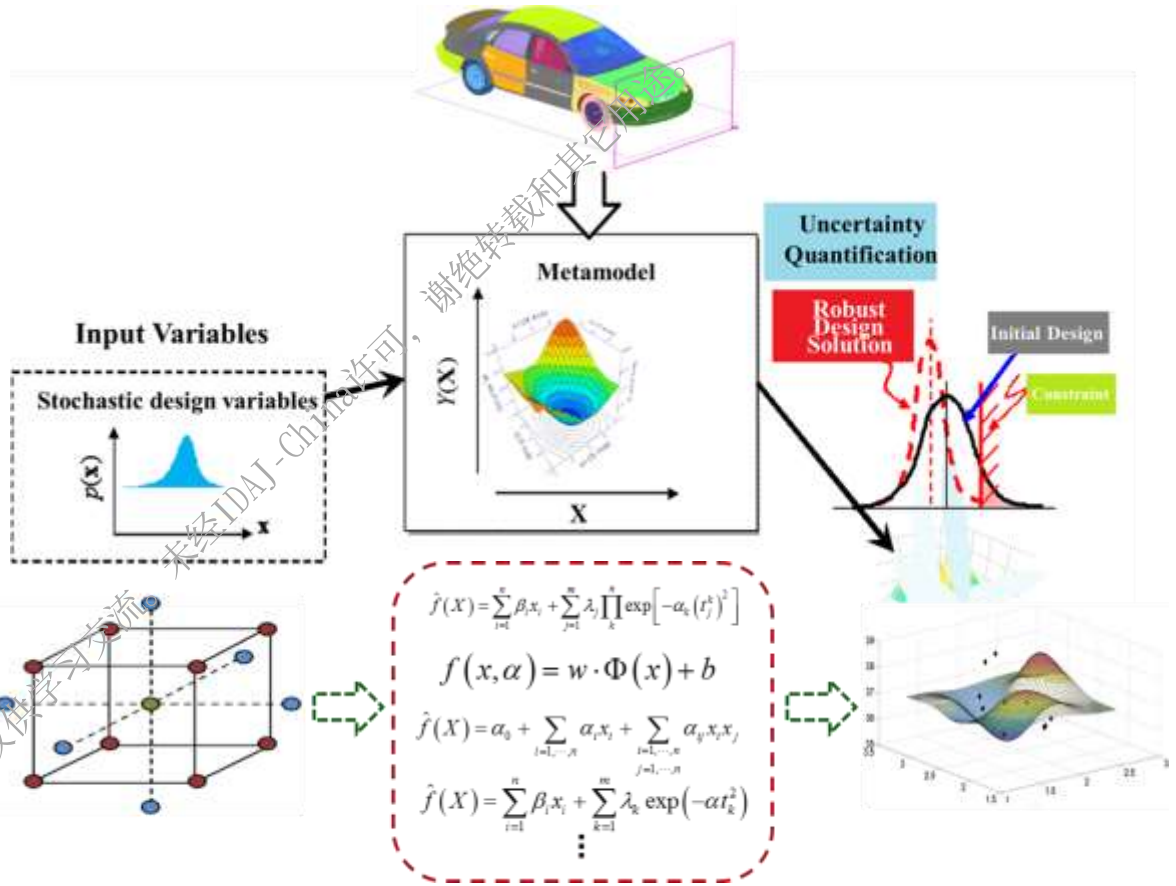


詹振飞 杨俊祺 舒雅静 杨仁杰，面向可靠性设计优化的响应面偏差修正方法, 中国机械工程，2015-1142

优化实例

近似模型建立

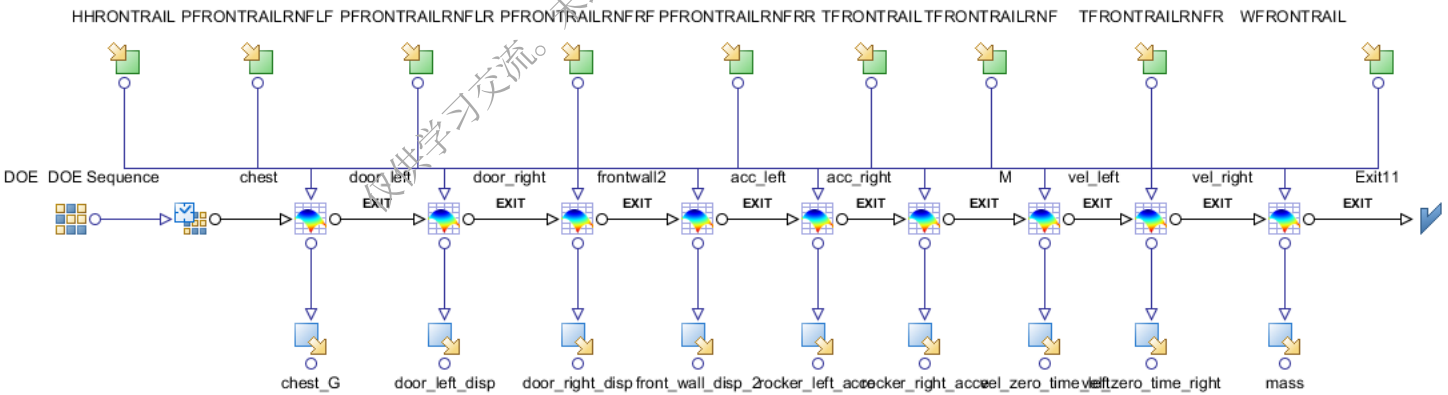
在面向汽车碰撞性能的优化过程中，由于有限元模型计算的耗时，需要将近似模型技术应用于优化迭代中。modeFrontier 提供了多种模型进行选择。



Junqi Yang, Zhenfei Zhan*, Chong Chen, et al., “Strategies for Metamodel Selection and Bias Correction in Reliability-based Design Optimization”, Engineering Optimization, GENO-2015-0509.

优化实例

基于现有模块的近似模型建立



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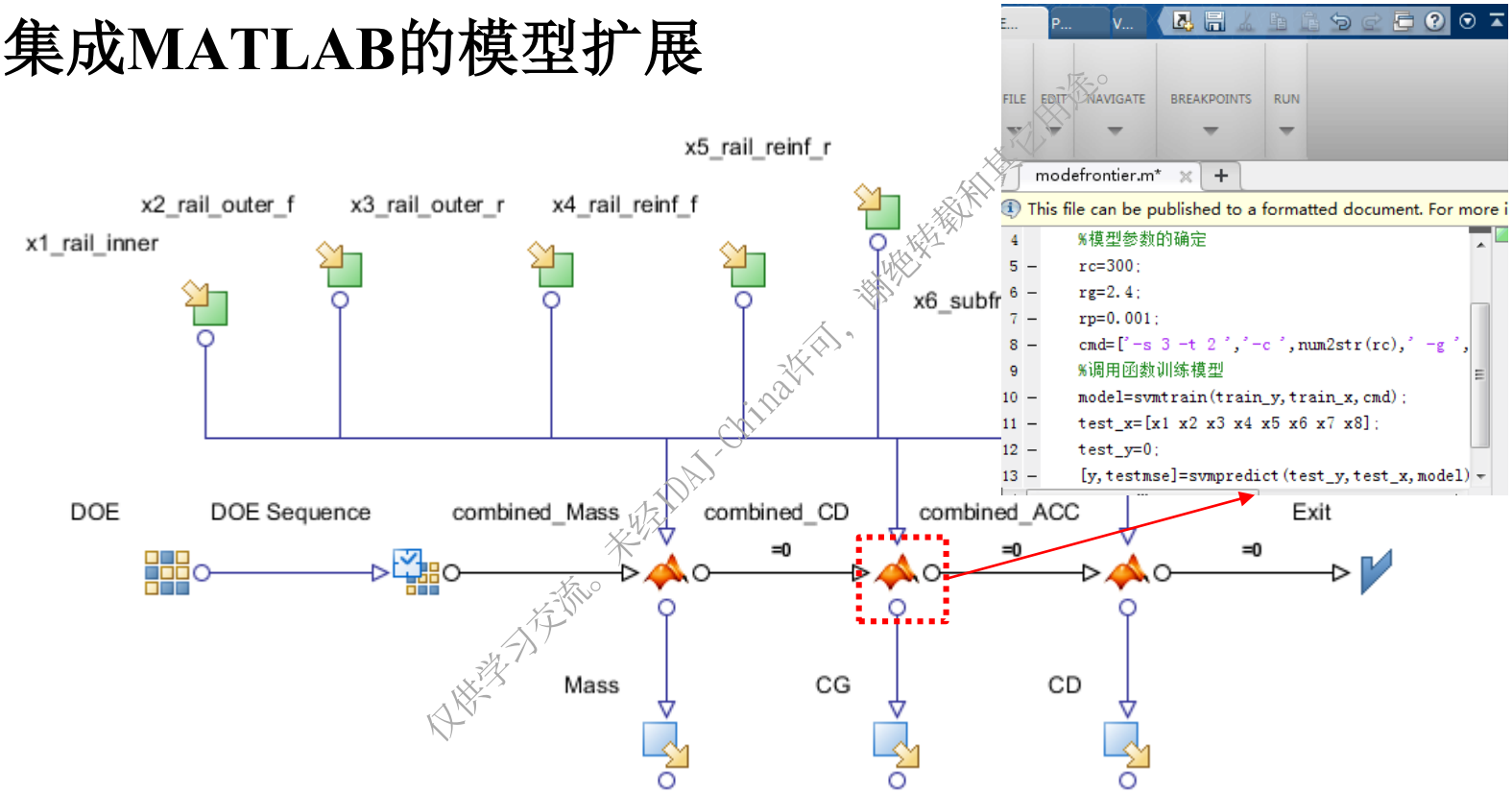
优化实例

集成MATLAB的模型扩展



对于某些modeFrontier尚未开发的近似模型，可集成其他编程语言进行模型扩展，如SVR。

Junqi Yang, Zhenfei Zhan*, Chong Chen, et al., “Strategies for Metamodel Selection and Bias Correction in Reliability-based Design Optimization”, Engineering Optimization, GENO-2015-0509.

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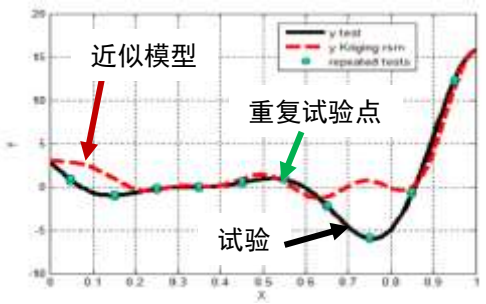
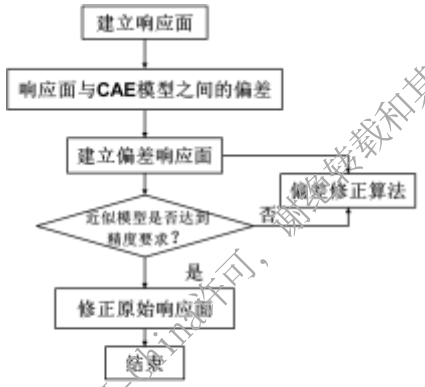
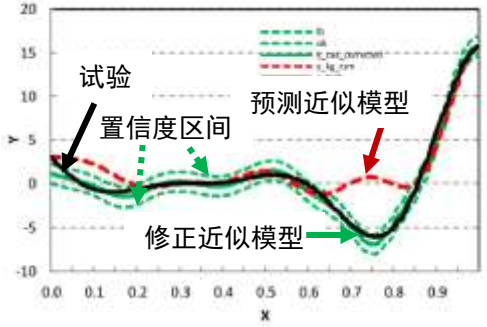
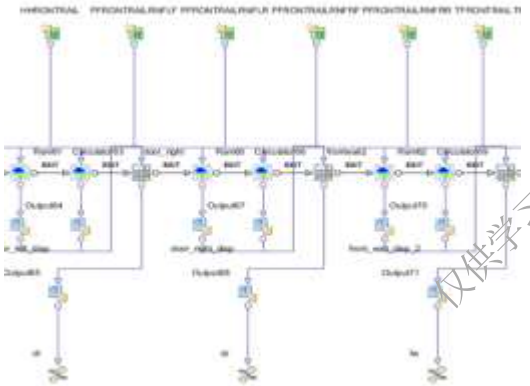
优化实例

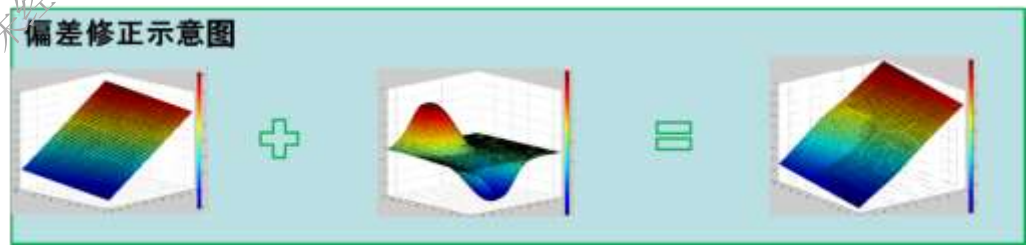
基于算法修正的模型建立











然而近似模型毕竟是真实FE莫得的有限近似，因此有必要结合偏差修正算法，在modeFrontier的平台上进行低精度模型的偏差修正及更新。

Junqi Yang, Zhenfei Zhan*, Chong Chen, et al., “Strategies for Metamodel Selection and Bias Correction in Reliability-based Design Optimization”, Engineering Optimization, GENO-2015-0509.

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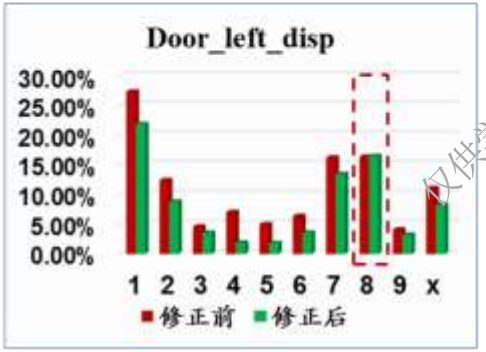
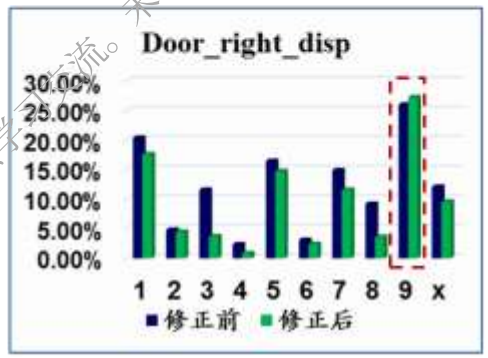
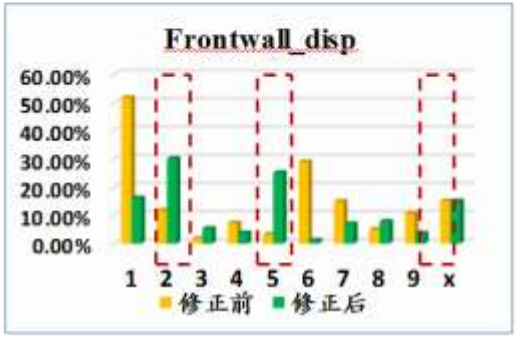
优化实例

修正前后比较

Relative Error		1	2	3	4	5	6	7	8	9	mean
Door_left_disp	修正前	27.42	12.45	4.62	7.07	5.02	16.41	16.29	16.44	4.14	11.09
	修正后	21.95	8.83	3.58	1.93	1.84	3.61	13.52	16.55	3.26	8.34
Door_right_disp	修正前	20.45	4.85	11.64	2.38	16.50	3.16	14.94	9.25	26.07	12.14
	修正后	17.64	4.50	3.73	0.85	14.78	2.45	11.63	3.63	27.30	9.61
Frontwall_disp	修正前	51.8	11.8	1.8	7.3	3.3	29.0	15.0	5.1	10.8	15.1
	修正后	16.2	30.2	5.4	3.8	25.2	1.2	7.0	7.9	3.6	15.1







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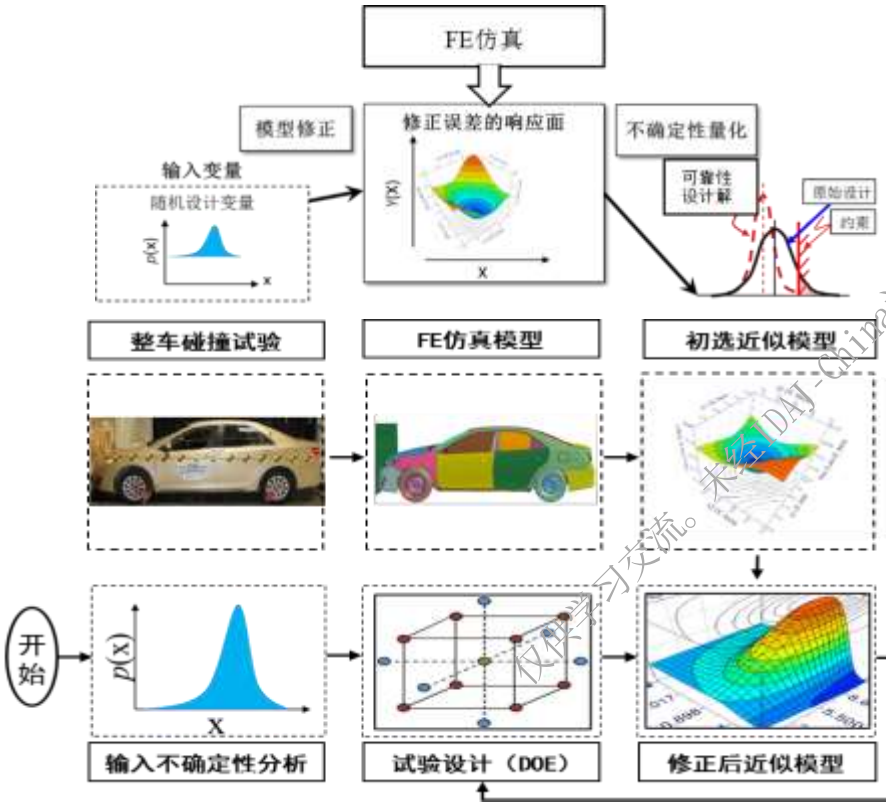
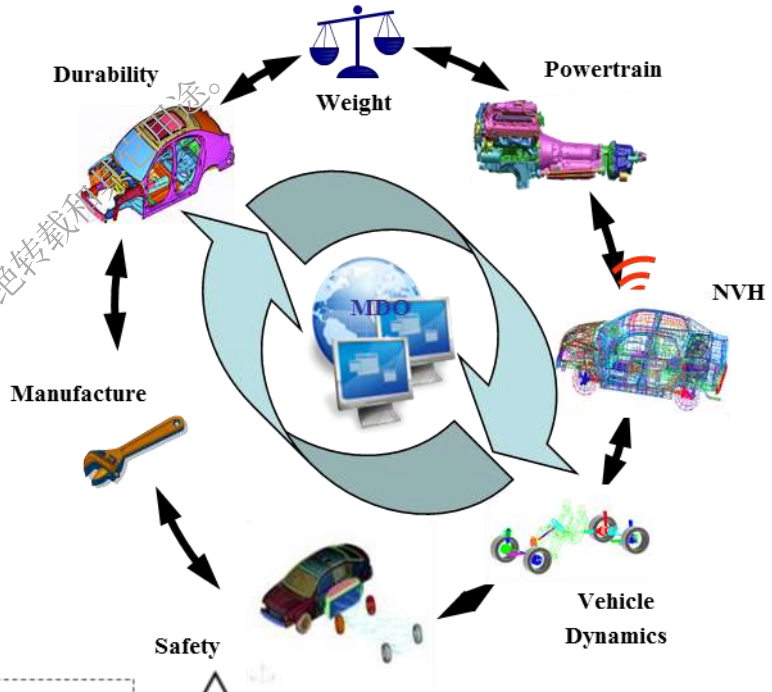
优化实例

- 不确定性下的多学科优化





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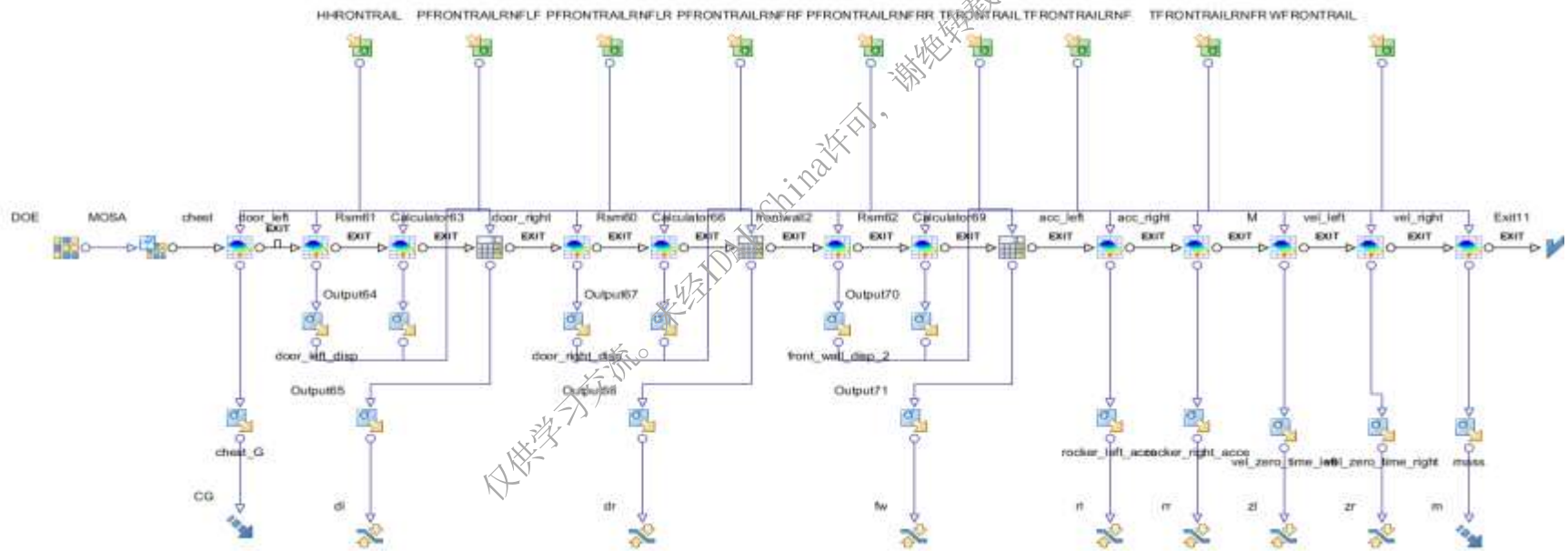
优化实例

- 不确定性下多学科优化模型



Junqi Yang, Zhenfei Zhan*, Chong Chen, et al., “Strategies for Metamodel Selection and Bias Correction in Reliability-based Design Optimization”, Engineering Optimization, GENO-2015-0509.

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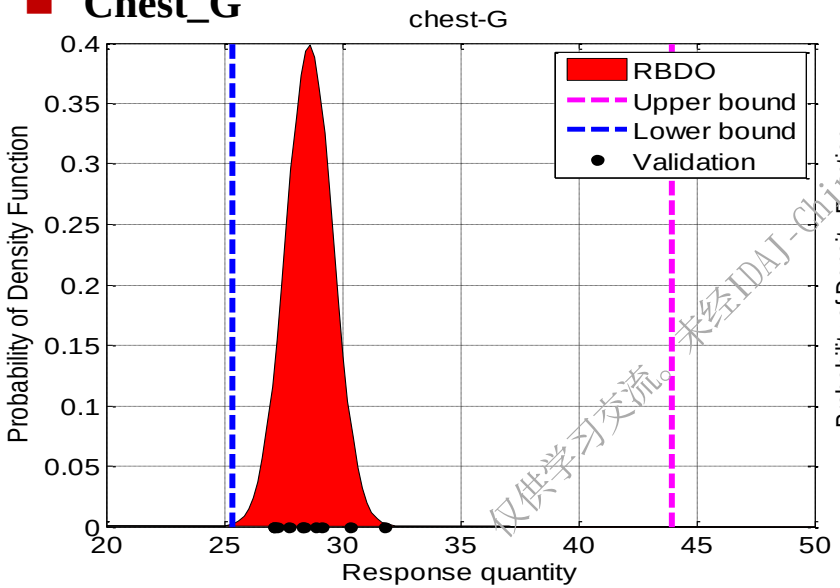
优化实例

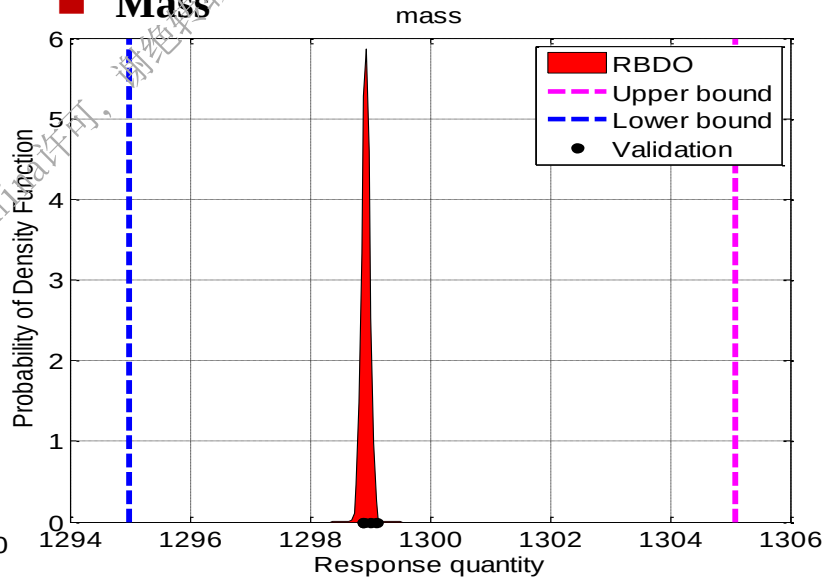
前端结构的优化

优化结果验证

Chest_G



Mass



- 由原始54组碰撞仿真数据得到其中Chest_G和Mass的最大值及最小值，分别作为二者的上下界。

若10组验证值均位于上下界构成区间的偏小值区域，则说明达到了优化目的。

Junqi Yang, Zhenfei Zhan*, Chong Chen, et al., “Strategies for Metamodel Selection and Bias Correction in Reliability-based Design Optimization”, Engineering Optimization, GENO-2015-0509.

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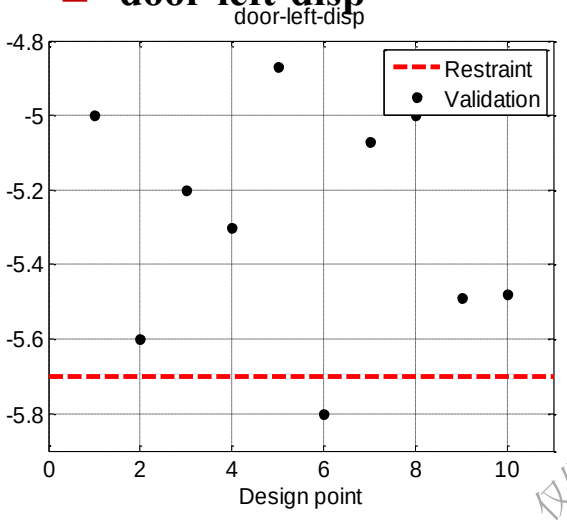
优化实例

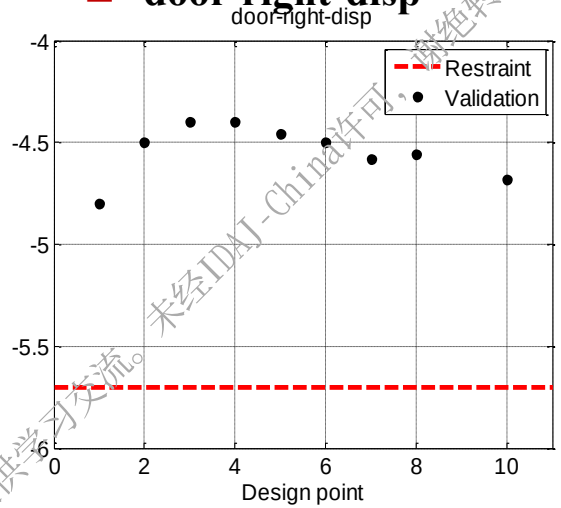
前端结构的优化

优化结果验证

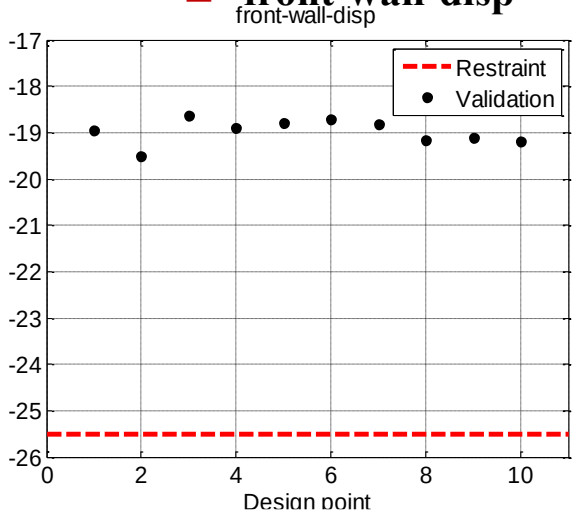
door-left-disp



door-right-disp



front-wall-disp



- 优化设计中，door-left-disp、door-right-disp、front-wall-disp三者的约束条件分别为小于5.7、5.7、25.5。可以看出，三个响应量， door-right-disp、front-wall-disp 的10组验证值均未超出约束范围，且留有较大裕度。door-left-disp10个验证值仅1个超出范围，为5.8。优化结果较好。

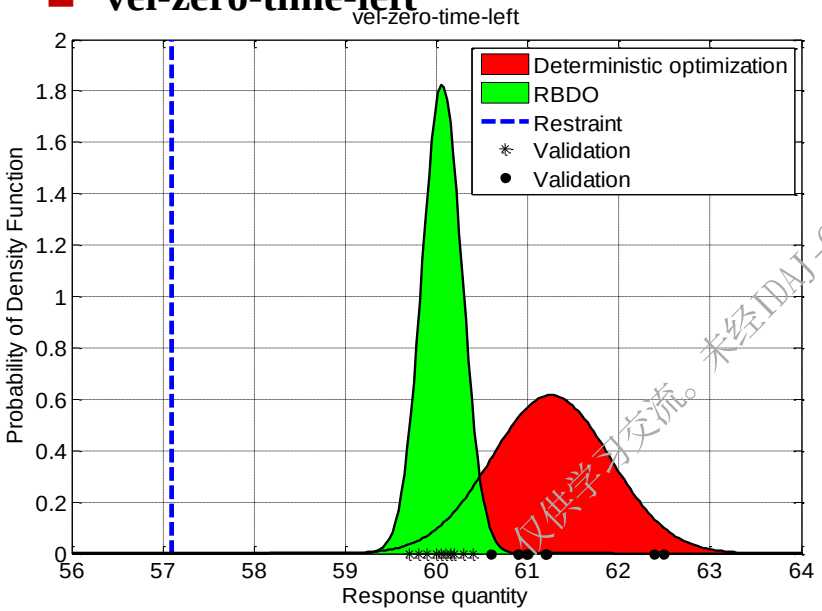
Junqi Yang, Zhenfei Zhan*, Chong Chen, et al., “Strategies for Metamodel Selection and Bias Correction in Reliability-based Design Optimization”, Engineering Optimization, GENO-2015-0509.

优化实例

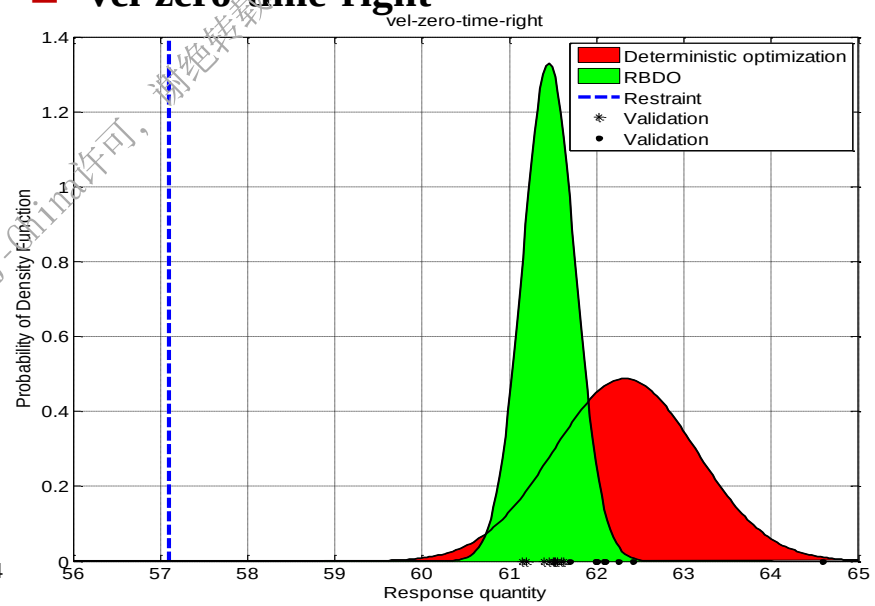
前端结构的优化

优化结果验证

vel-zero-time-left



vel-zero-time-right



为了验证所得优化解的稳定性，将确定性优化的结果同样生成10组验证数据，通过对比稳健优化解和确定性优化解的均值与方差，进行可靠性及稳健性的判断。

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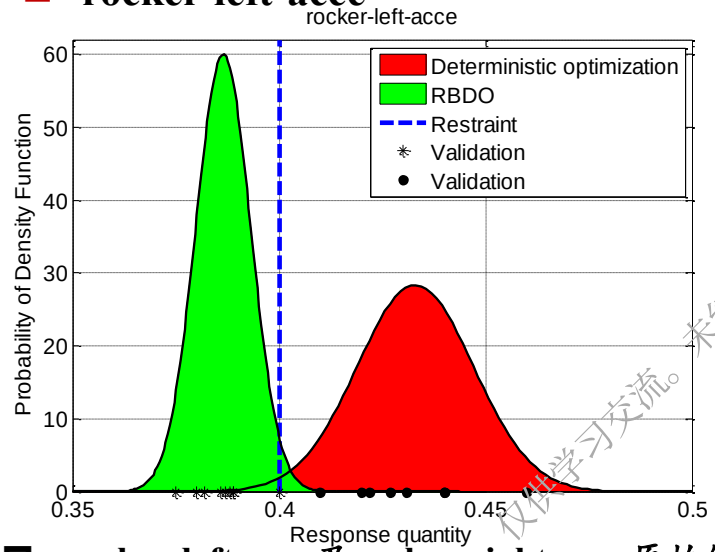
优化实例

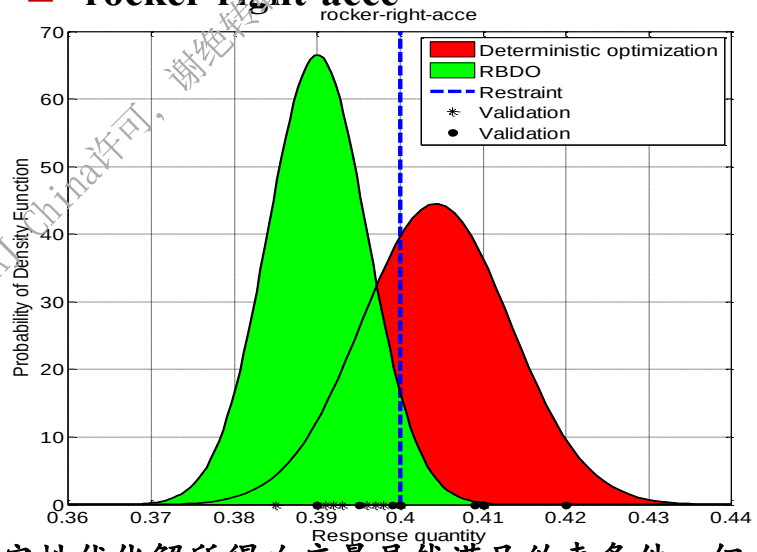
前端结构的优化

优化结果验证

rocker-left-acce



rocker-right-acce



rocker-left-acce及rocker-right-acce原始的确定性优化解所得响应量虽然满足约束条件，但是通过对设计变量添加微小扰动后得到的10组验证值大部分超出约束范围0.4，同时分布也较分散。因此最终优化解不仅在稳健性上、同时在可靠性上均优于确定性优化解。

Junqi Yang, Zhenfei Zhan*, Chong Chen, et al.,“Strategies for Metamodel Selection and Bias Correction in Reliability-based Design Optimization”, Engineering Optimization, GENO-2015-0509.

Thank You !