CAESES在全船优化上的应用

上海船舶研究设计院

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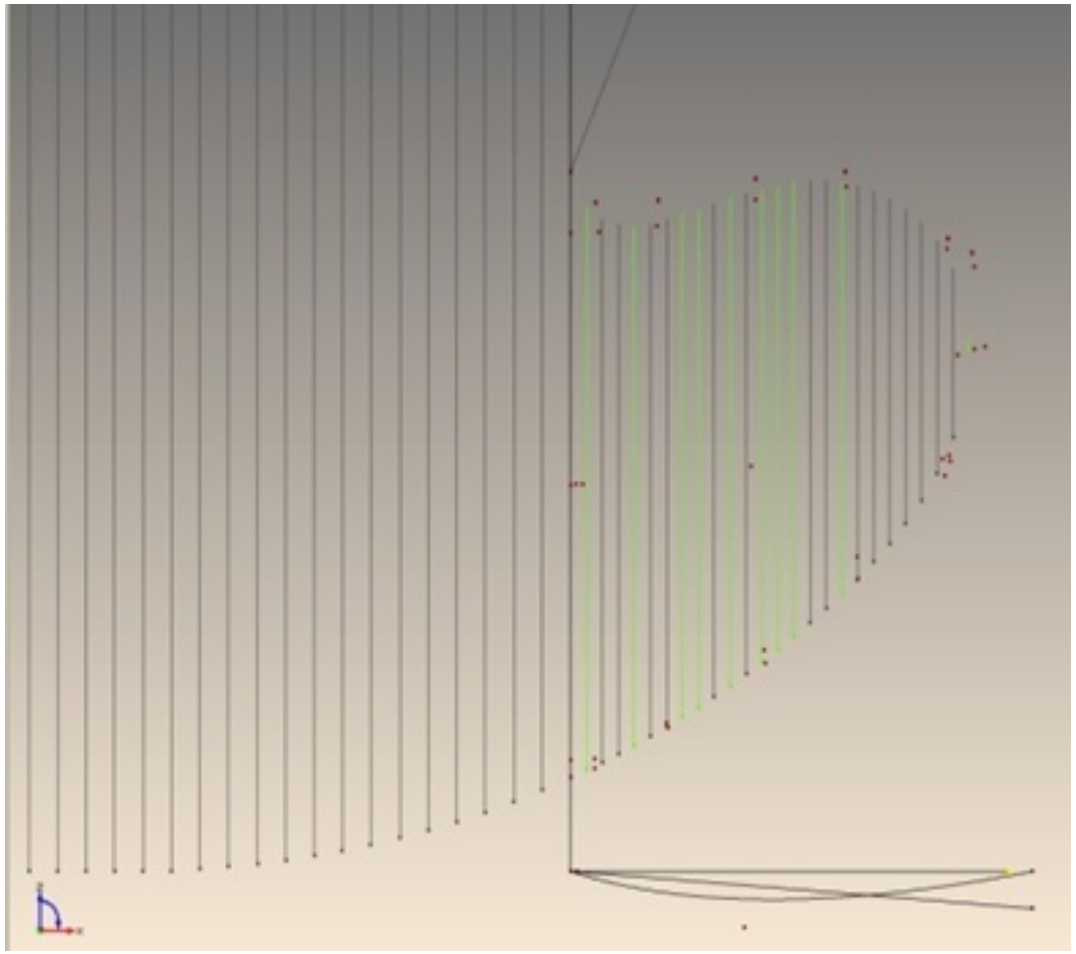
主要内容

- 半参数变换
- 全参数建模
- 优化方法
- 应用实例
- 小结

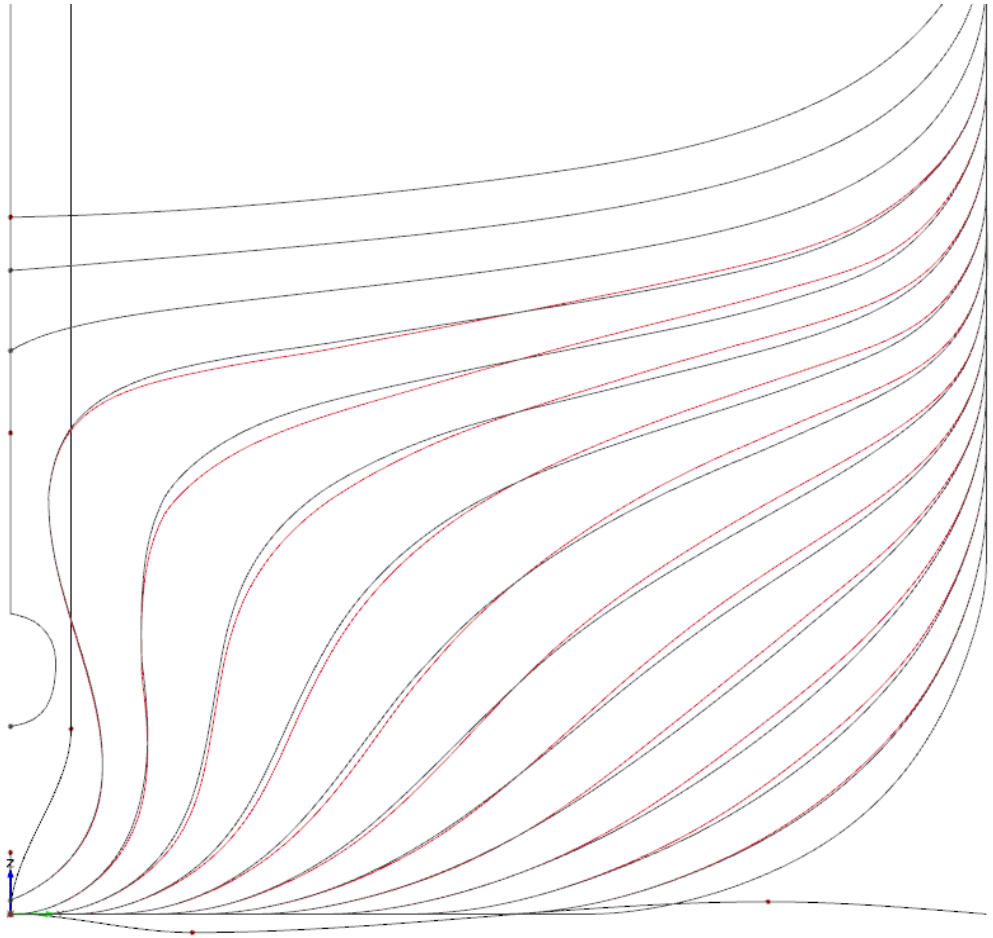
半参数变换

- Delta Shift + Delta Sum
  - 球首长度和高度变换



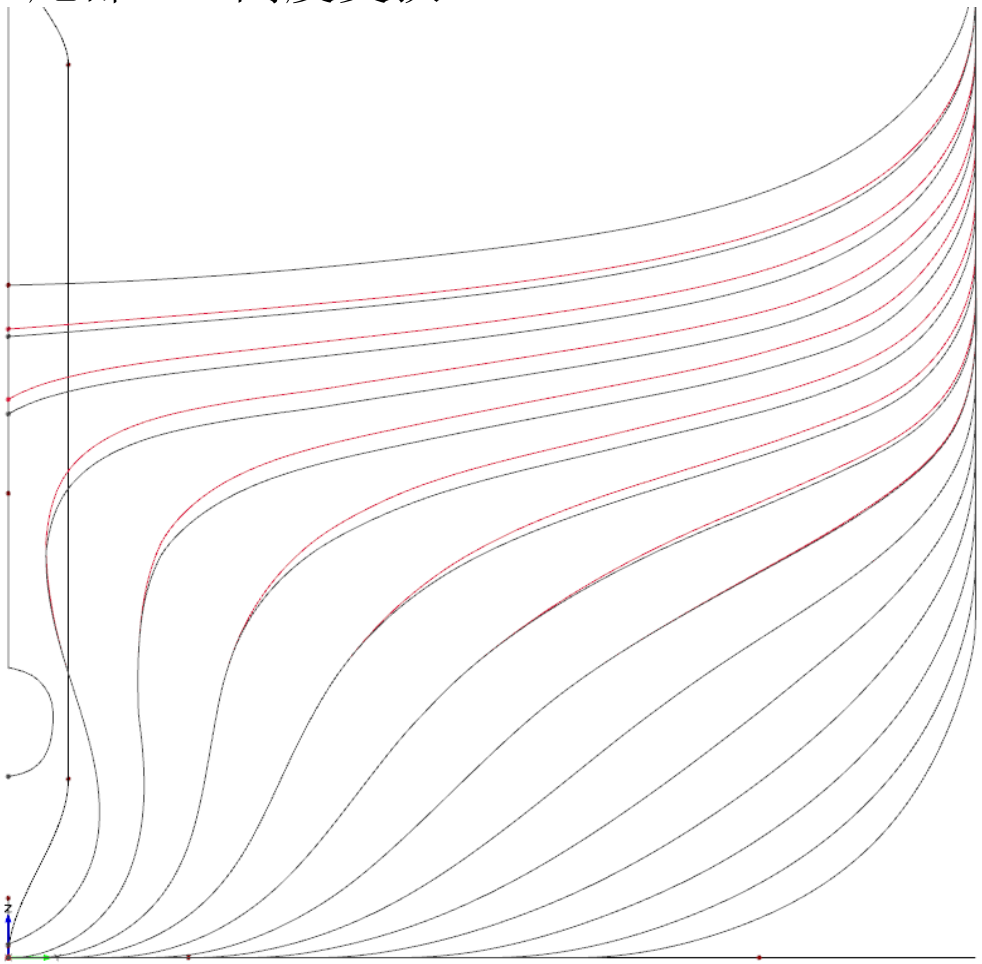
半参数变换

- Delta Shift + Delta Product
  - 尾部uv度变换



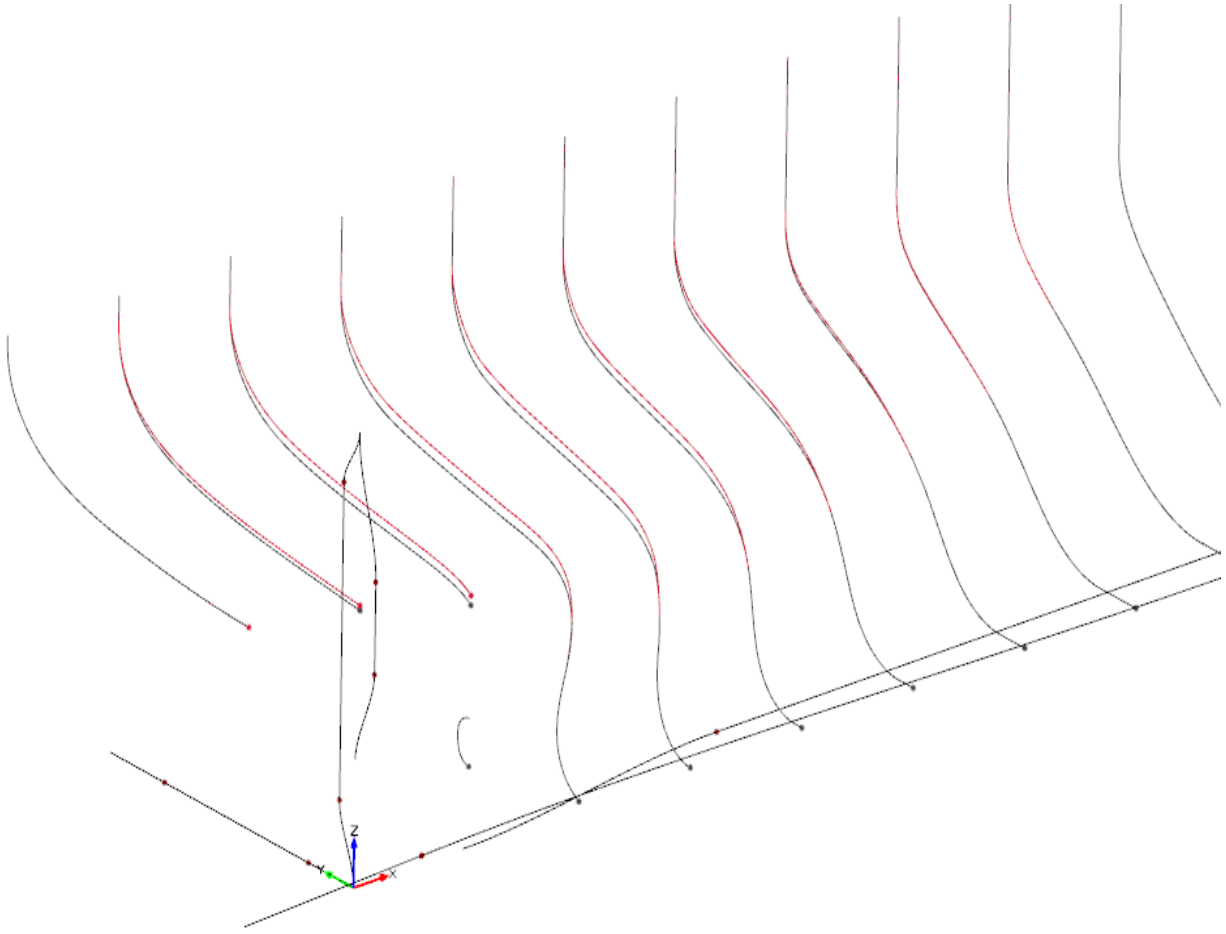
半参数变换

- Delta Shift + Delta Product
  - 尾部keel高度变换



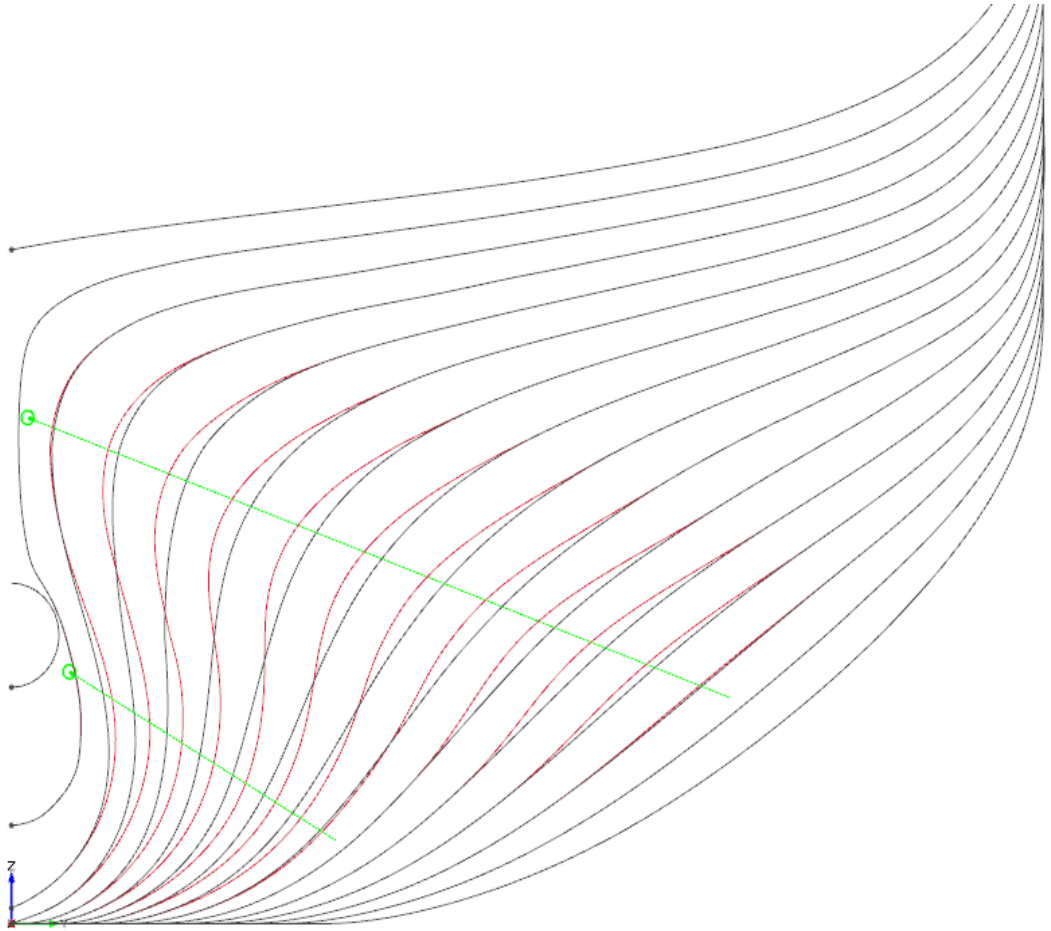
半参数变换

- Delta Shift + Delta Product
  - 尾部keel高度变换



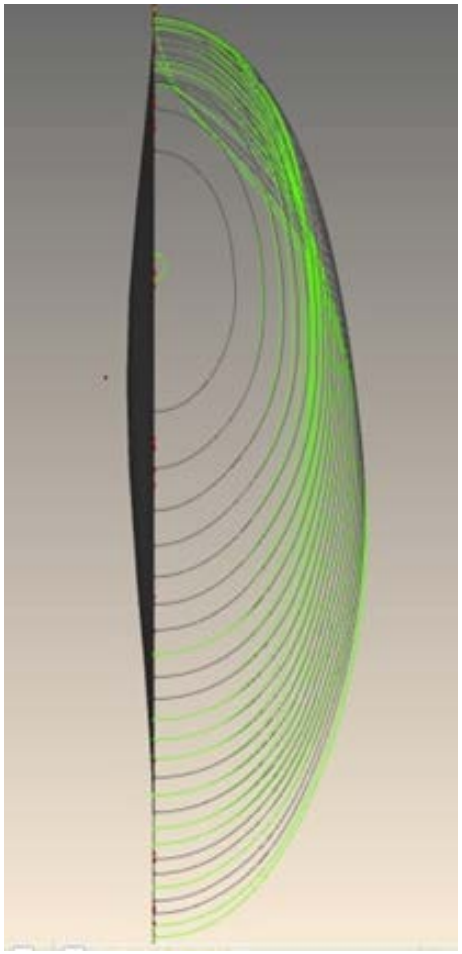
半参数变换

- Cartesian Shift
  - 球尾UV变换



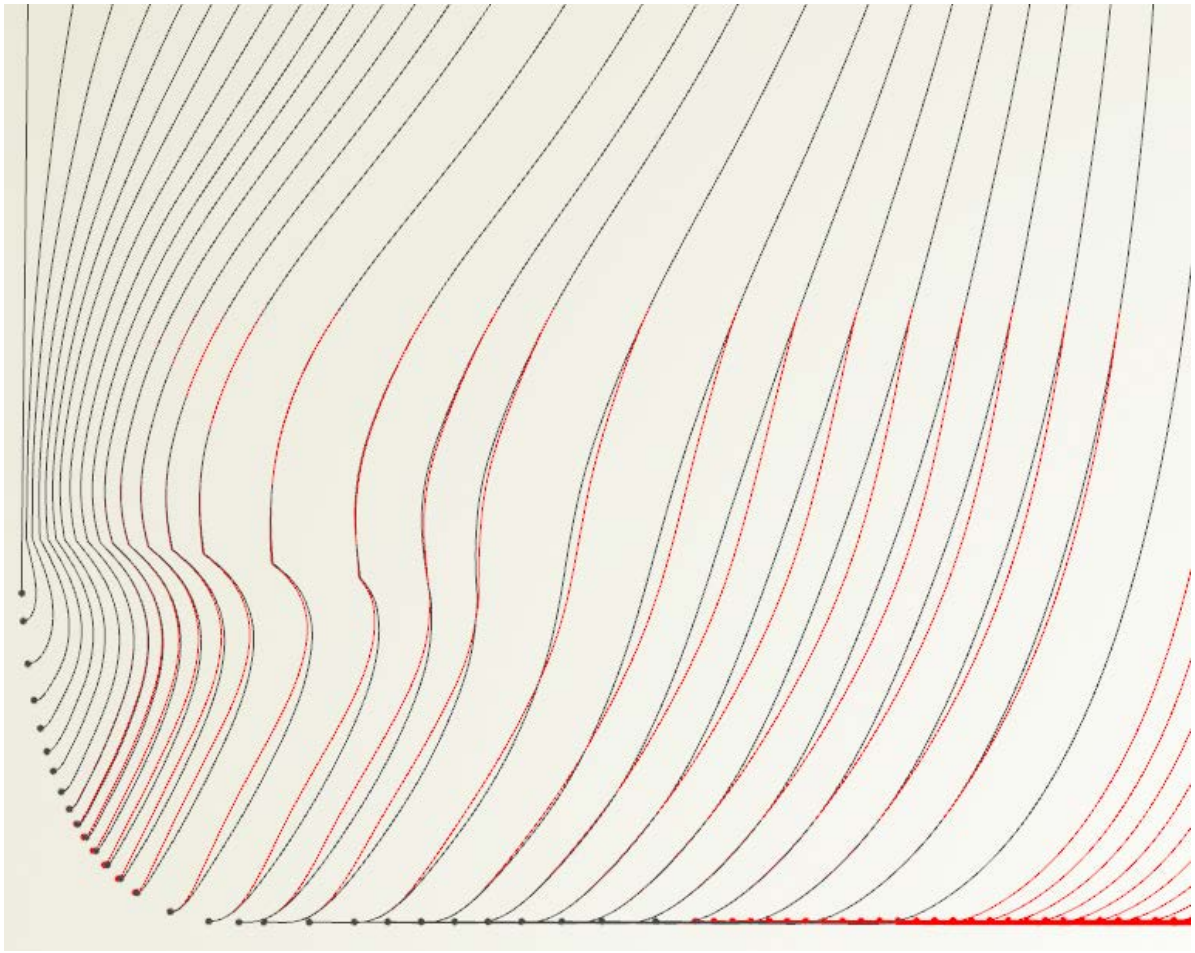
半参数变换

- Surface Delta Shift
  - 球首半宽变换



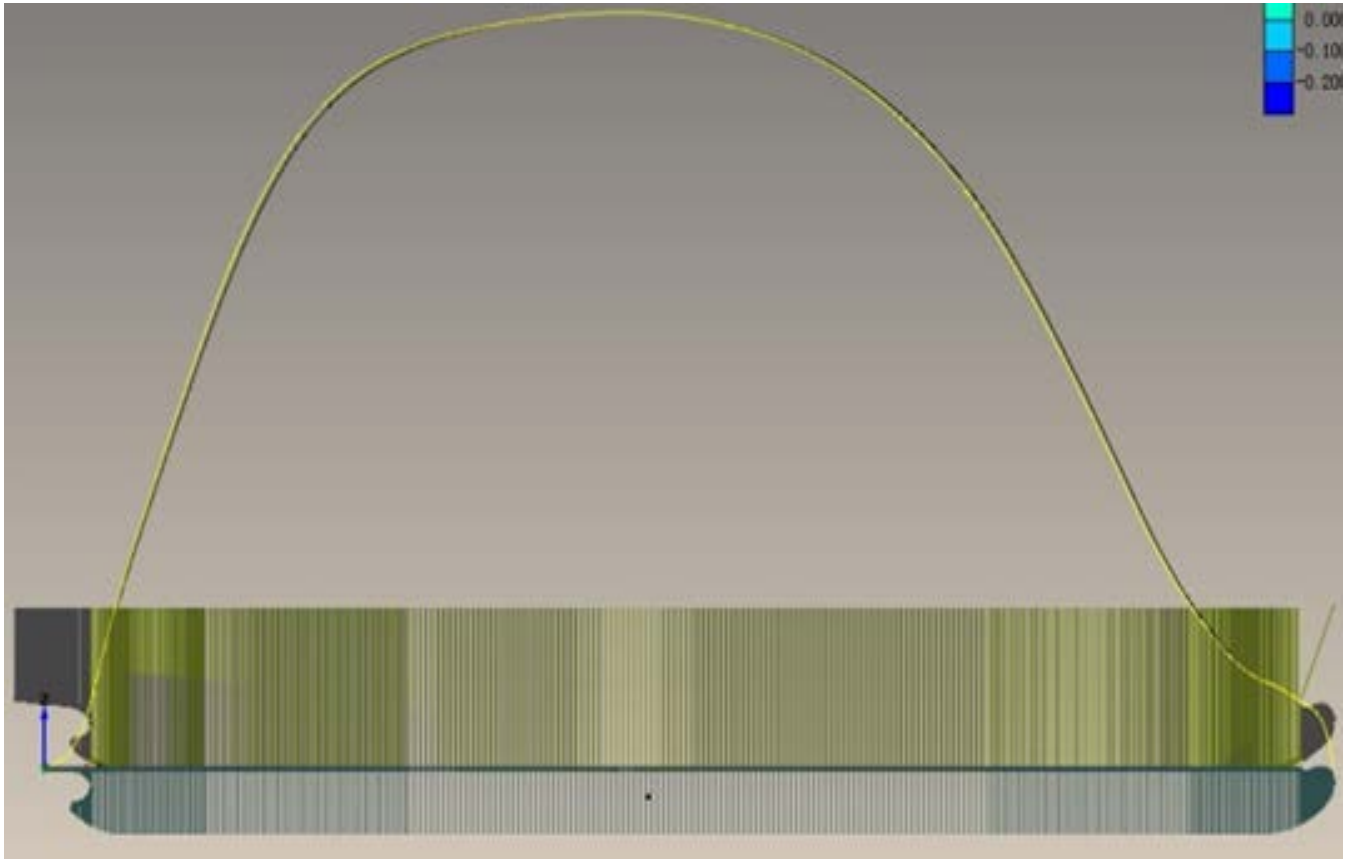
半参数变换

- Surface Delta Shift
  - 首部UV变换



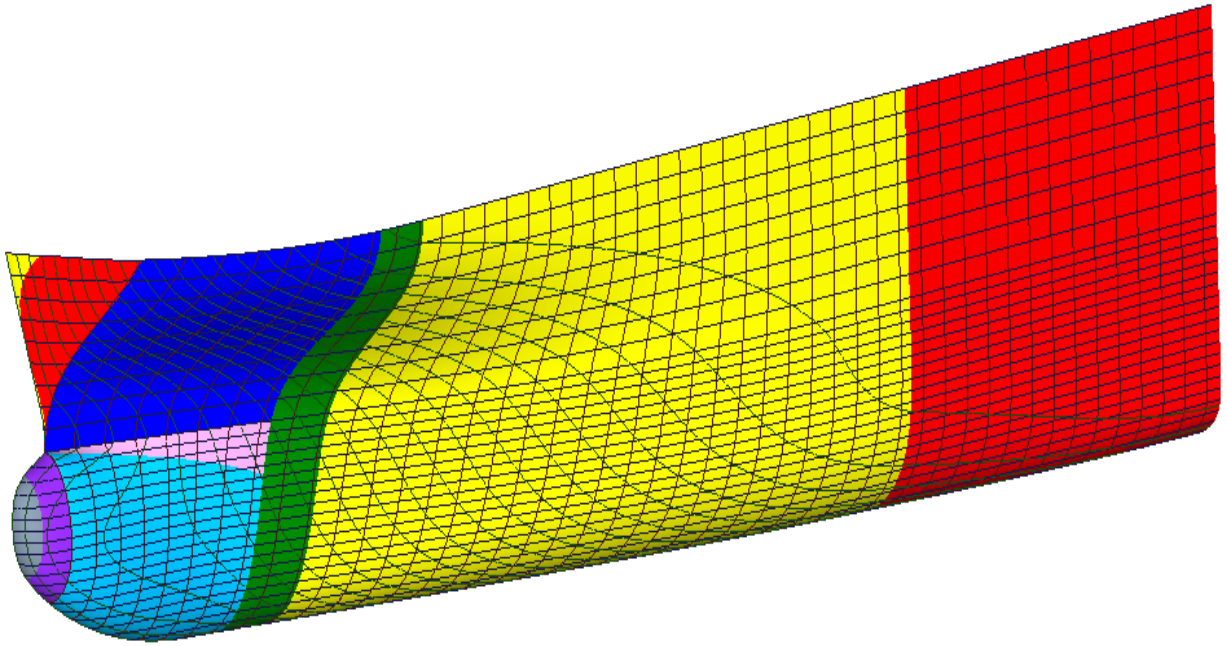
半参数变换

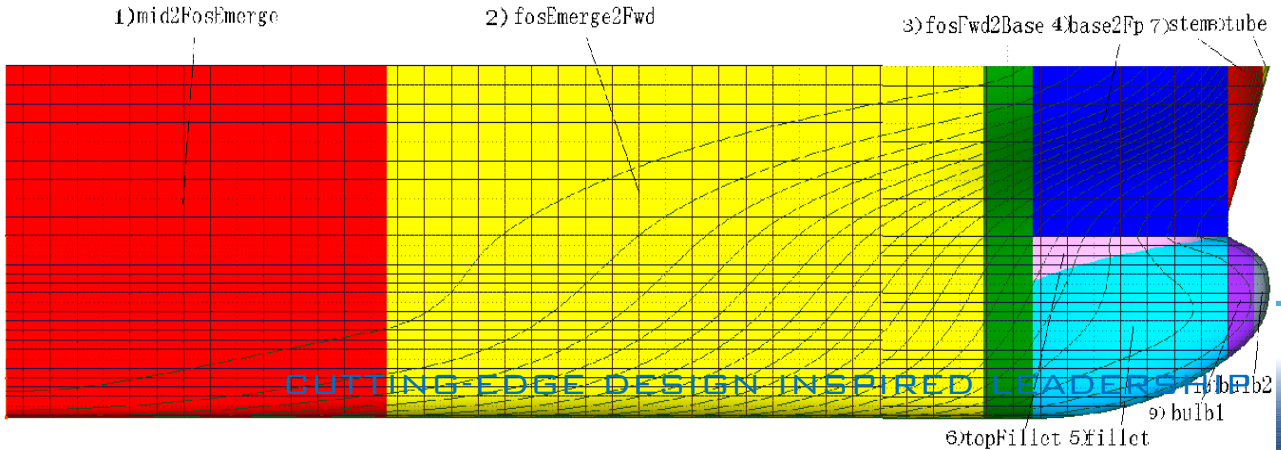
- Lackenby Shift
  - sac曲线变换（排水量、浮心位置、平行中体、进流段、去流段等变换）



全参数建模

- 首部模型曲面图





参数

特征曲线

曲面

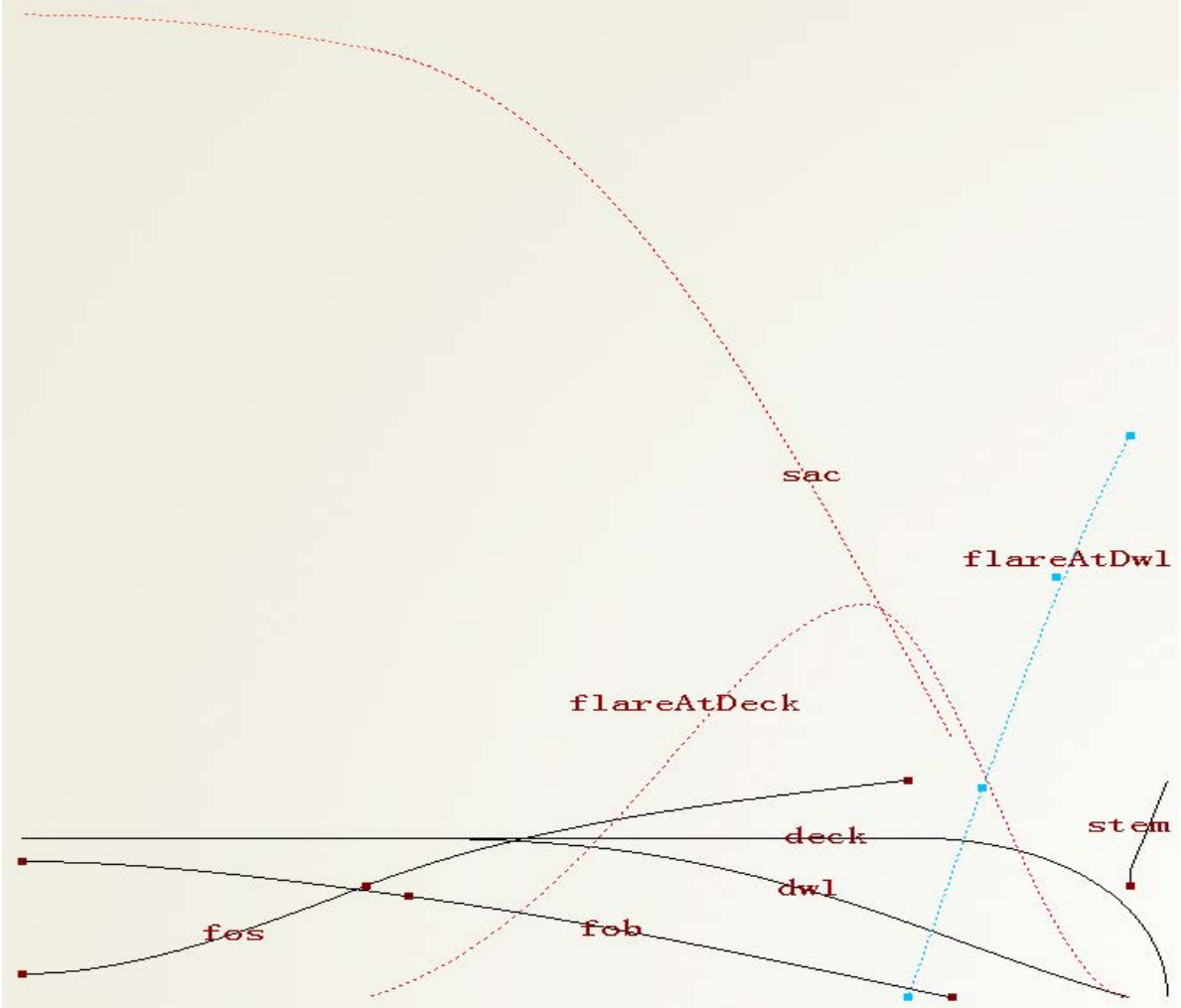
全参数建模

- 首部参数

✓ xFp：垂线间长
✓ beam：船宽
✓ draft：吃水
✓ height：型深
✓ bowOverang：球首长度
✓ xPeak：最前端x位置，xFp+bowOverang
✓ xMainFrame：最大横剖面的位置
✓ bilgeHeight：舭部高度
✓ bilgeWidth：舭部宽度
✓ relXFwdBase：平底线前端位置系数
✓ xFwdBase：平底线前端位置

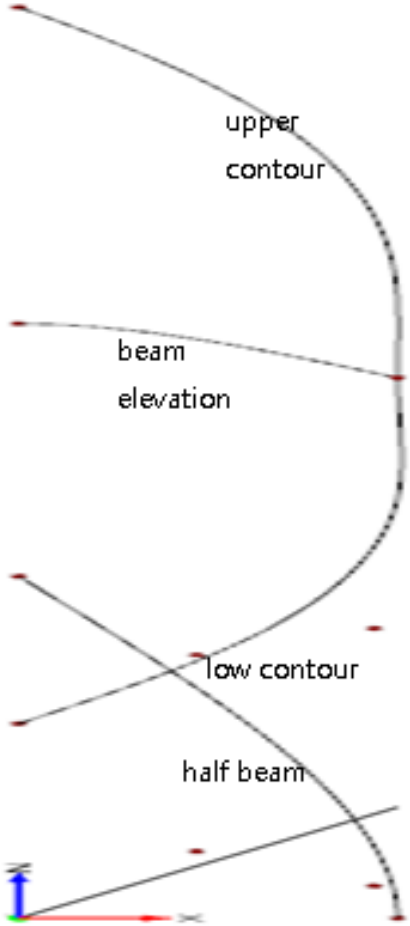
全参数建模

- 首部特征曲线



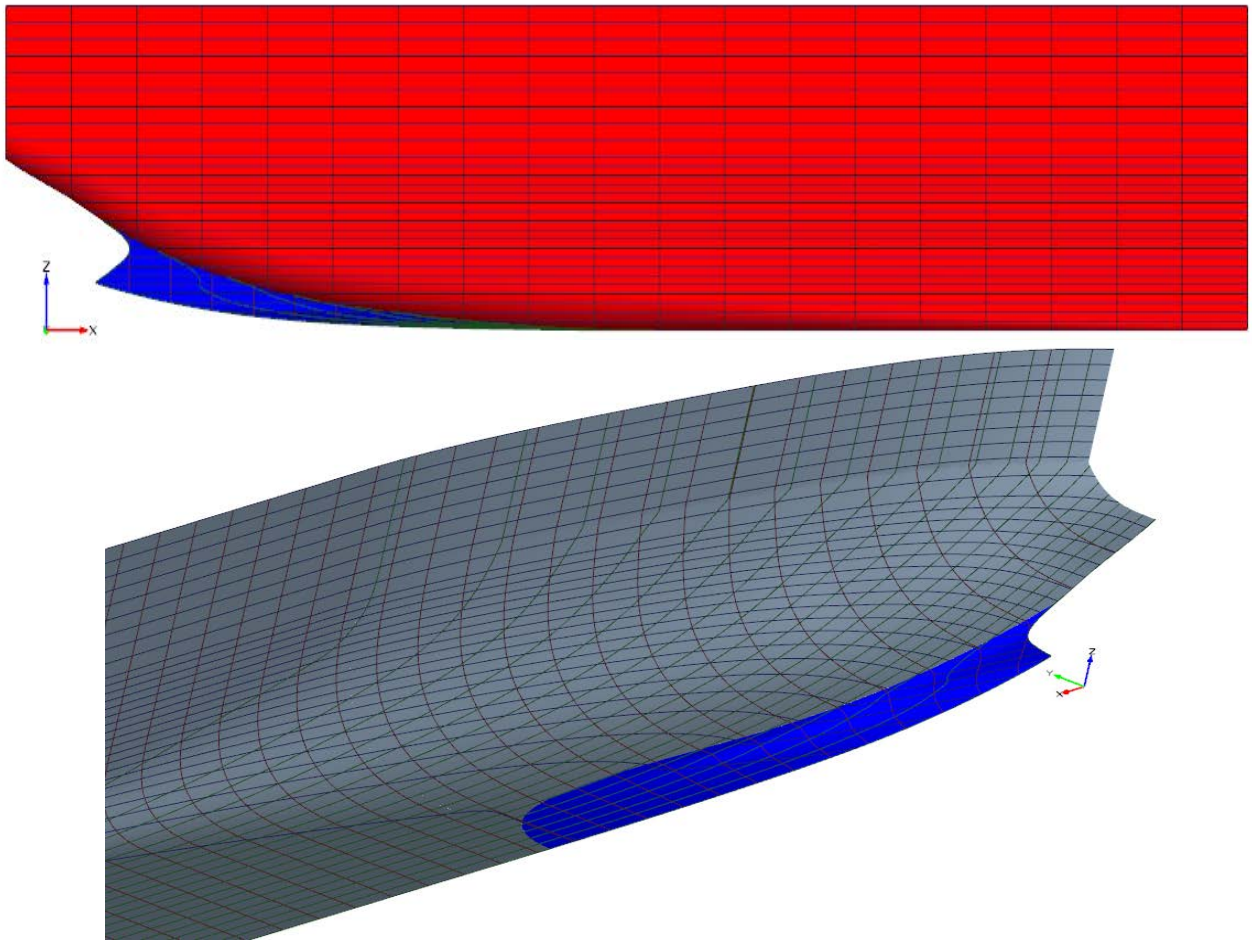
全参数建模

- 首部特征曲线
  - 球首特征曲线



全参数建模

- 尾部模型曲面图



全参数建模

- 尾部部参数

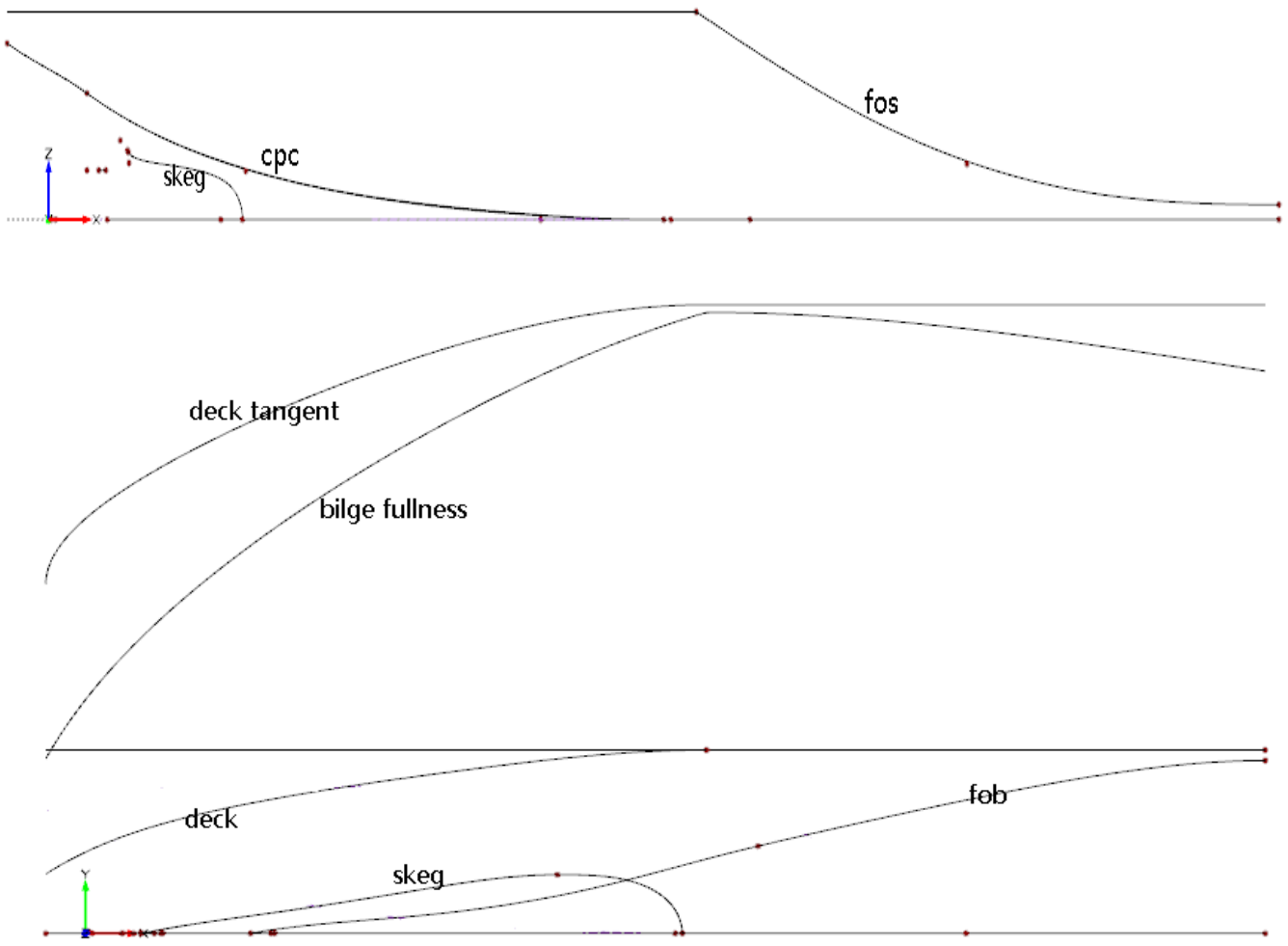
✓ xTransom：尾封板后端x位置

✓ zTransom：尾封板后端z位置

✓ xMainFrame：最大横剖面的位置

全参数建模

- 尾部特征曲线



全参数建模

- 尾部特征曲线
  - Skeg过度线

|abdy|curveEngines|forSkeg

Coordinate System	Z - (X,Y)
From	
Start Curve	abdy|functions|fairingBoundary| outer
Second Curve	abdy|functions|fairingBoundary| inner
Extension on Start	100
Intermediate	
Third Curve	abdy|functions| fairingIntermediate| intermediate
Weight	[abdy|functions| fairingIntermediate| forWeight:curve, 4.5]
Loc	
T Value	[abdy|functions|forX, 1]
To	
Fourth Curve	abdy|functions|bossing| innerCircle
End Curve	abdy|functions|bossing| outerCircle
Extension on End	5

优化方法

- 优化算法
  - ✓ Sobol
  - ✓ Tsearch
  - ✓ Dakota

- 参数限制
  - ✓ Contraint （hardpoint，maxVolm，minVolm）

优化案例1 - 基于Operational profile的优化

- Operational profile -12500mpv多用途船

平均吃水（m）	航速（kn）							
	9	10	11	12	13	14	15	合计
4.5	0.25	0.28	0.65	0.89	1.98	2.60	0.80	7.5
5.0	0.16	1.56	0.75	4.11	7.02	9.10	3.08	25.8
5.5	0.21	0.37	1.10	3.05	5.22	6.09	2.13	18.2
6.0	0.41	0.75	1.28	2.21	3.57	4.14	2.61	15.0
6.5	0.07	0.44	1.32	1.88	2.54	3.09	1.35	10.7
7.0	0.07	0.07	0.64	2.13	2.42	2.78	0.60	8.7
7.5	0.00	0.21	0.68	2.72	3.30	3.39	1.06	11.4
8.0	0.18	0.00	0.00	0.20	0.19	0.18	0.06	0.8
合计	1.4	3.7	6.4	17.2	26.3	31.4	11.7	98.1

简化的Operation profile

平均吃水（m）	尾倾（m）	航速（kn）				
		12	13	14	15	合计
5.5	1.65	11	-	16	-	27
6.5	0.5	13	-	24	16	53
7.5	0.0	-	20	-	-	20
合计	-	24	20	40	16	100

优化案例1 - 基于Operational profile的优化

- 首部优化参数

(1) tipElevation_bulb，初始值：5.691，变化范围：4.5~5.9；另外，为保证变换的合理性，首垂线位置下端的高度LowElevationAtFp_bulb也随球首前端高度变化而相关联变化。

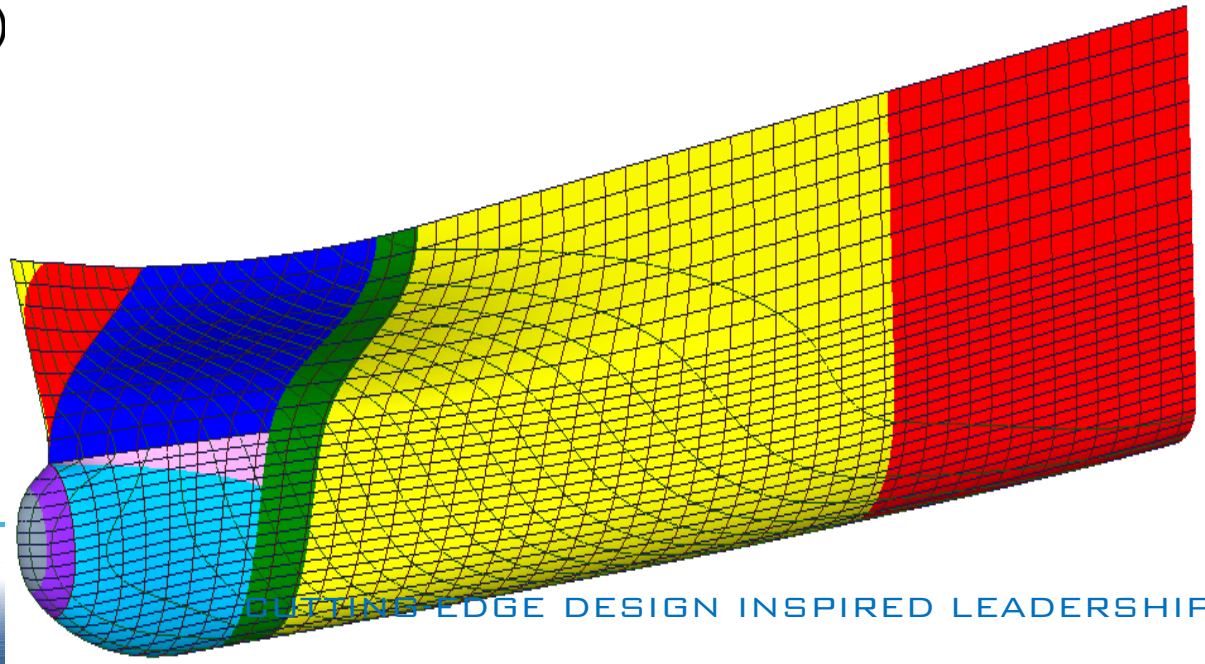
设定LowElevationAtFp_bulb= tipElevation_bulb×0.46178176。

(2) halfBeam_bulb，初始值：1.537，变化范围：1.3~1.8；

(3) dwl_fullness，初始值：0.665，变化范围：0.62~0.72；

(4) dwl_entryangle，初始值：18°，变化范围：15°~26°；

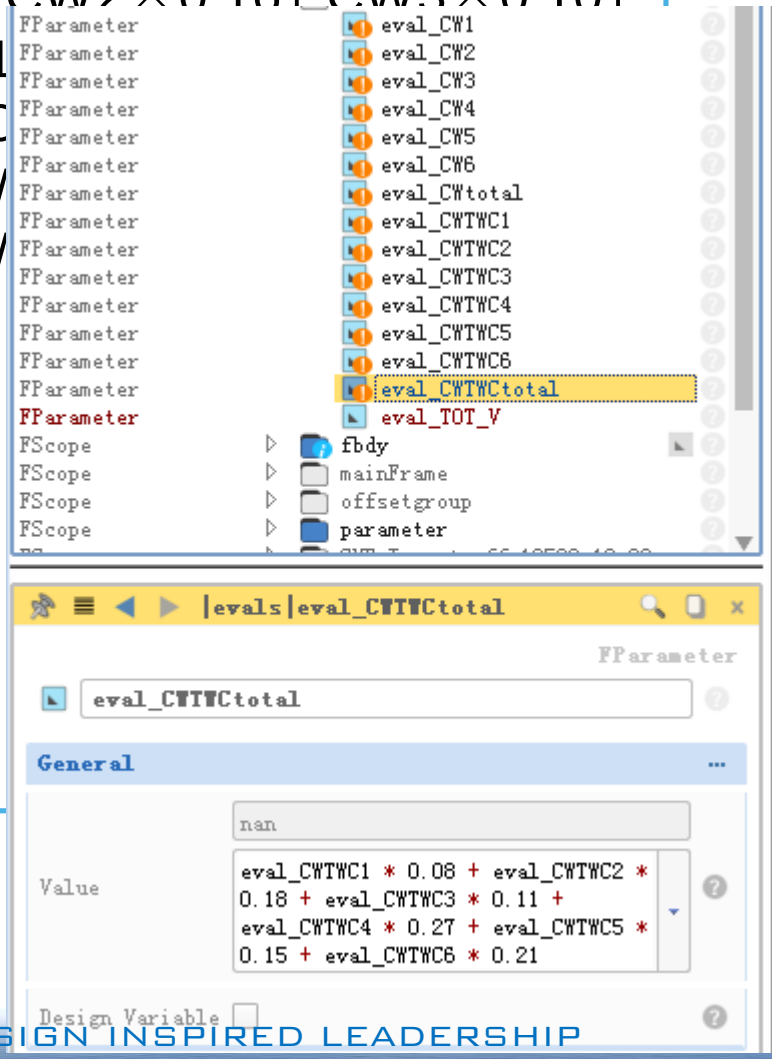
(5)



优化案例1 - 基于Operational profile的优化

- 权重设置

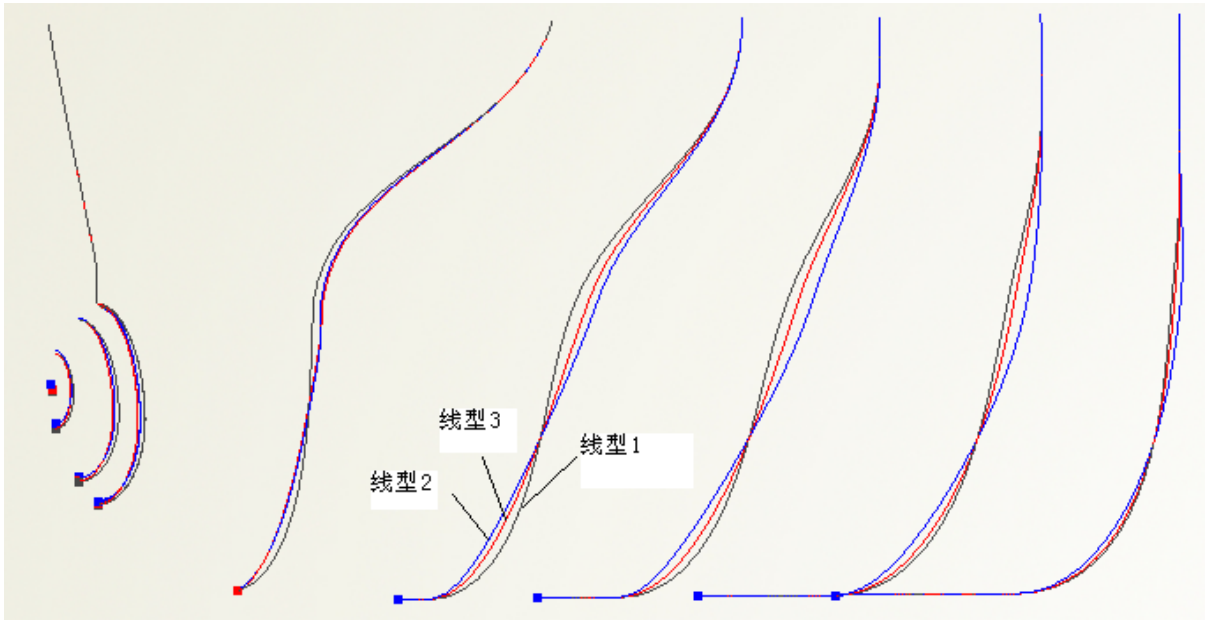
CW_weighted=CW1×0.07+ CW2×0.16+ CW3×0.10+
CW4×0.26+ CW5×0.21
CWTWC_weighted=CWTWC
CWTWC2×0.16+ CWTV
CWTWC4×0.26+ CWTV
CWTWC6×0.20



优化案例1 - 基于Operational profile的优化

	dwl_entryan	dwl_full	flare_max	dv_tipElevat	dv_halfBeam	eval_CTtota	eval_CTT
Attribute	Active	Active	Active	Active	Active		
Name	**dwl_entryan…**	**dwl_full**	**flare_max**	**dv_tipElevat…**	**dv_halfBeam…**	**eval_CTtotal**	**eval_CTTCt…**
Scope	varibles	varibles	varibles	varibles	varibles	evals	evals
Reference							
Lower Bound	15.582031	0.62078125	18.132812	4.5054688	1.3039063	0.00094922533	0.00013012136
Upper Bound	25.917969	0.71921875	34.867188	5.8890625	1.7960938	3.2892624e+38	2.7950858e+42
Feasible Designs: 62.857143 %							
Mean Utilization Index							
Mean	20.701367	0.67030692	26.354855	5.1833594	1.5482422	7.3094721e+36	6.2113017e+40
Sample Standard Deviation	3.0515735	0.0289054	4.8988393	0.40625508	0.14594809	4.9033429e+37	4.1666679e+41
Error-free: 62.857143 %	100 %	100 %	100 %	100 %	100 %	64.285714 %	64.285714 %
Sobol_02_des0026	21.160156	0.68328125	25.304688	5.6921875	1.3039063	0.0009981378	0.00013012136
Sobol_02_des0042	21.488281	0.70515625	30.085938	5.4734375	1.4445313	0.0010093534	0.00013191555
Sobol_02_des0033	17.878906	0.66453125	30.617188	5.7796875	1.3351563	0.0010672347	0.00013297888
Sobol_02_des0043	24.113281	0.63015625	34.335938	5.1234375	1.3195313	0.0011347202	0.00013319399
Sobol_02_des0021	18.699219	0.63796875	23.976562	4.7953125	1.3273438	0.0011283673	0.00013410421
Sobol_02_des0036	20.503906	0.68953125	34.867188	4.7296875	1.4601563	0.0010801115	0.00013436558
Sobol_02_des0002	22.964844	0.69109375	28.757812	5.8890625	1.3742188	0.0009953185	0.00013437698
Sobol_02_des0024	16.074219	0.71296875	19.726562	5.8453125	1.4523438	0.00097815411	0.00013488841
Sobol_02_des0027	23.785156	0.65828125	21.054688	4.6421875	1.4289063	0.0011233833	0.00013506186
Sobol_02_des0039	21.816406	0.65203125	32.742188	5.2546875	1.3976563	0.0011139816	0.0001353641
Sobol_02_des0015	23.292969	0.64421875	31.414062	5.5828125	1.4835938	0.0011650869	0.00013666003
Sobol_02_des0012	19.355469	0.70671875	33.539062	5.0578125	1.4210938	0.00099480287	0.00013687339
Sobol_02_des0014	25.917969	0.71921875	27.164062	4.5328125	1.3585938	0.00094922533	0.00013750725
Sobol_02_des0008	16.402344	0.67859375	30.882812	5.3640625	1.3117188	0.0010080727	0.00013769897
Sobol_02_des0045	20.175781	0.64265625	27.960938	4.5984375	1.3820313	0.001134123	0.00013788931
Sobol_02_des0029	19.847656	0.64578125	23.179688	5.1671875	1.4914063	0.0011702381	0.00013823753
Sobol_02_des0003	25.589844	0.66609375	33.007812	4.8390625	1.4992188	0.0011464684	0.00014013149
Sobol_02_des0034	23.128906	0.71453125	22.117188	5.0796875	1.5851563	0.0010575735	0.00014025769
Sobol_02_des0022	23.949219	0.68796875	32.476562	5.4953125	1.5773438	0.0010858473	0.00014122344

优化案例1 - 基于Operational profile的优化

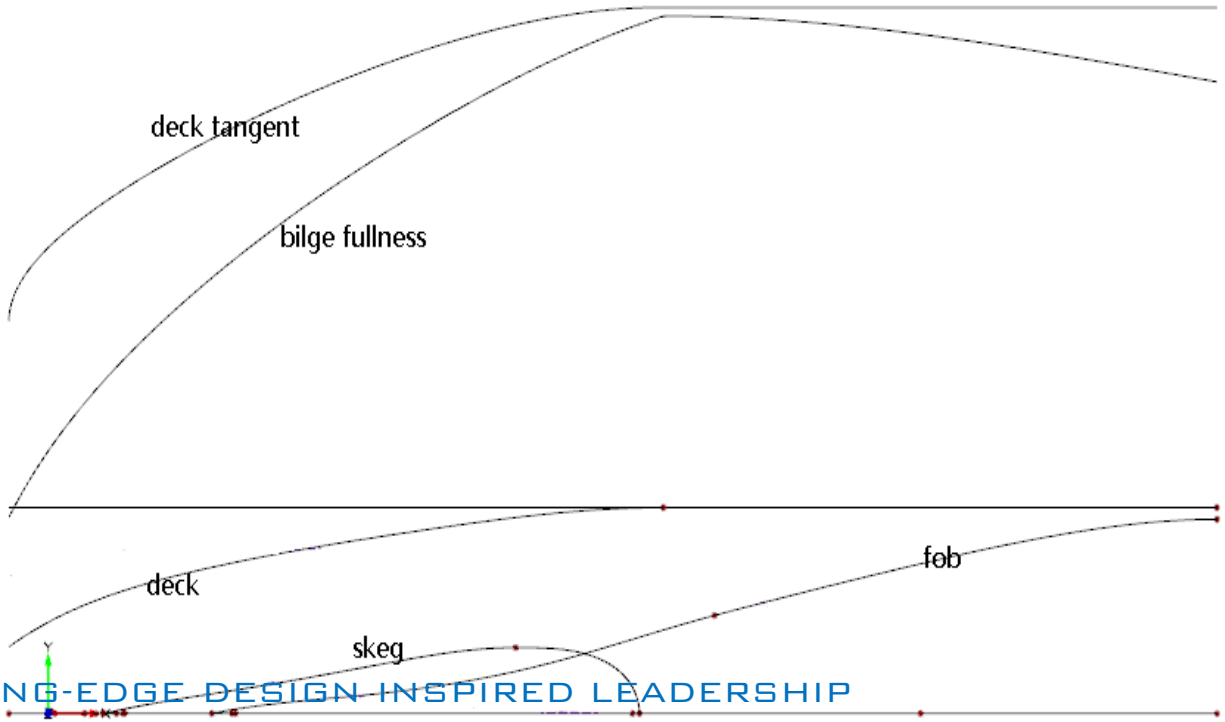


- 黑色的线型1为原始线型，而蓝色的线型2和红色的线型3是选出的2个最好的方案。由此看来优化的方案均呈现放大设计水线，减小舭部的趋势，由于设计吃水所占权重较小，优化的方案更多地提高了5.5m和6.5m吃水的性能，符合线型设计的经验。由计算结果可以看出，2个方案加权兴波阻力系数均大为减小，兴波也明显改善

优化案例1 – 全船优化（散货船）

- 尾部优化参数

✓ aft_bilge_fullness_max
✓ aft_bilge_fullness_part1
✓ aft_xdeckmax
✓ aft_dk_part1_fullness
✓ aft_dk_part1_Tangent
✓ aft_dk_tangent_part1_fullness
✓ aft_skeg_widt



优化案例1 – 全船优化（散货船）

- 优化变换方法

✓ 全参数
首部全参数建模
尾部全参数建模

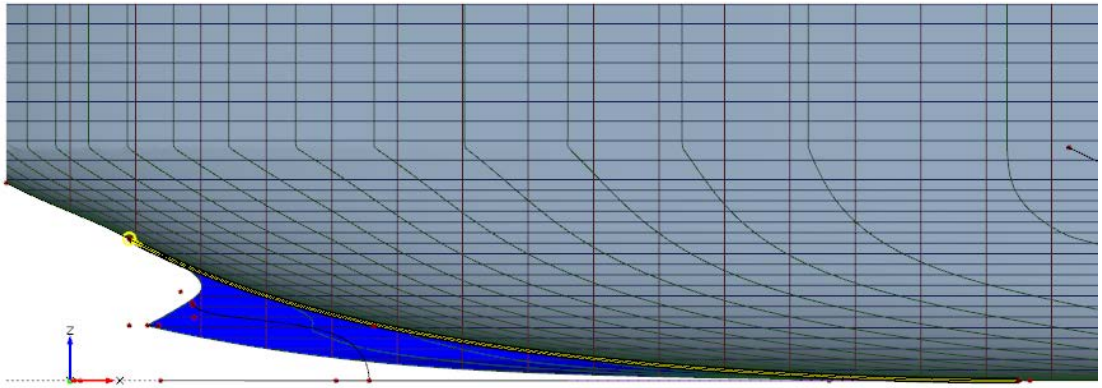
✓ 半参数
首部uv度变换
尾部uv度变换
球尾uv度变换
尾部keel高度变换

优化案例1 – 全船优化（散货船）

- 尾部优化参数

✓ aft_widthFactor_Value

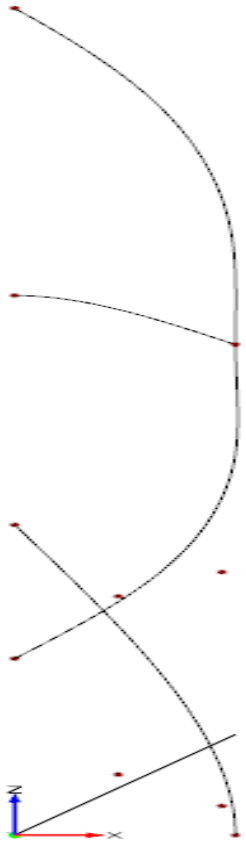
✓ aft_cpc2_fullness
✓ aft_xTransom_Value
✓ aft_zTransom_Value
✓ aft_ytransom_Value



优化案例1 – 全船优化（散货船）

- 首部优化参数

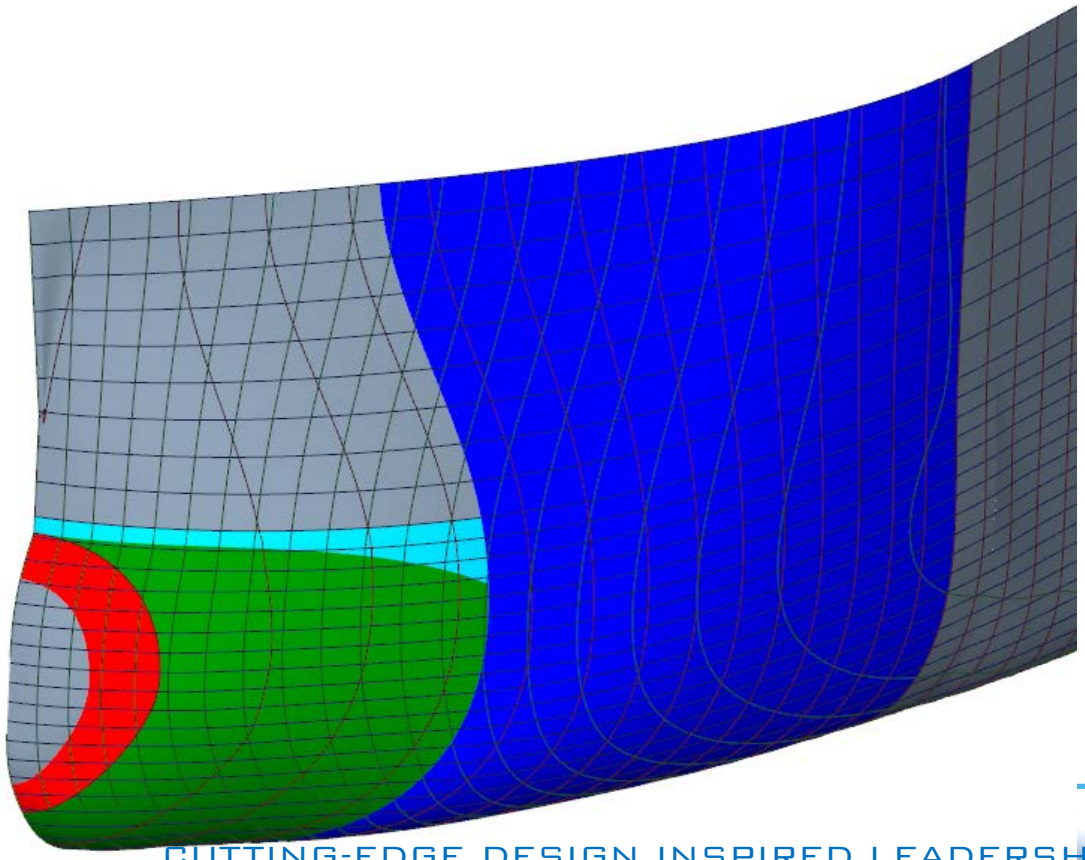
✓ bulb_bulbLength
✓ bulb_bulbLowfullness
✓ bulb_bulbLowSectionFullness
✓ bulb_bulbtipElevation
✓ bulb_bulbTopElevationAtFp
✓ bulb_bulbTopFulness
✓ bulb_bulbTopSectionFullness
✓ bulb_dv_bulbLowElevationAtFp_rati
✓ bulb_halfBeamBulbAtFp
✓ bulb_halfBeamElevationAtFp
✓ bulb_halfBeamFullness



优化案例1 – 全船优化（散货船）

- 首部优化参数

✓ dwl_entryangel
✓ dwl_fullness
✓ flare_max



总结

- Caese提供了多样的线型变换以及优化算法并提供多种CFD工具整合

- 针对不同船型、不同优化目标可选取不同的建模和变化方法


SDARI
Thank You !
AUSTRALIA
OCEANIA
NEW ZEALAND
VANUATU
TONGA