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# Optimization of new centrifugal pump with space guide vane

Shanghai KSB Pump Co., LTD.

Li Haifeng  
2017-10-27





## 强大的生产基地

### 上海凯士比泵有限公司

- 坐落于上海闵行工业园区
- 占地137,000平方米
- 上海凯士比有限公司是上海电气与KSB集团的合资公司
- 注册资金2700万美金
- 总投资2980万美金
- 约900 员工



# 国内现有销售网络

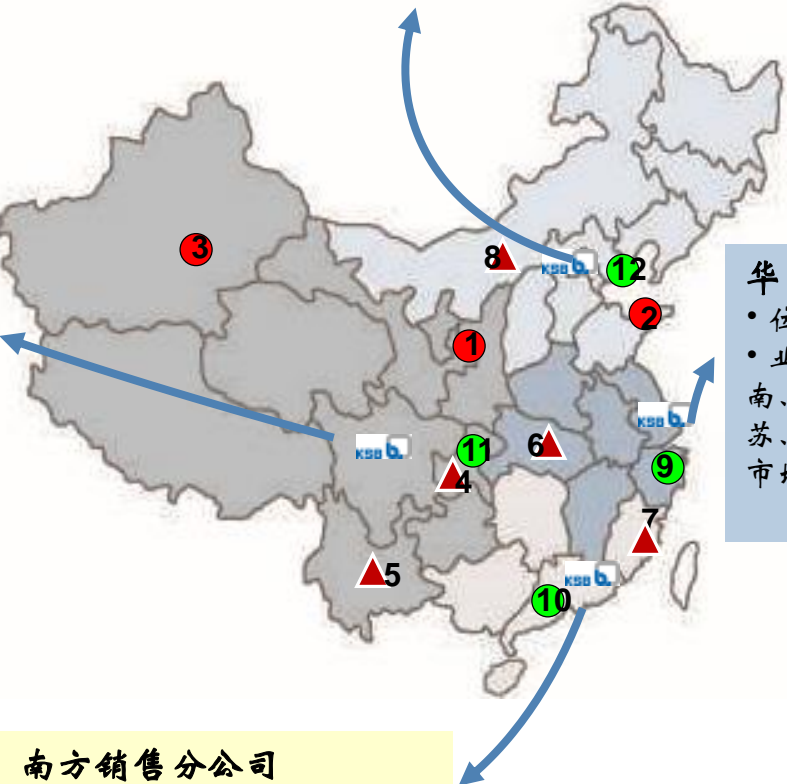
## KSB 分公司

- 办事处
  1. 西安
  2. 青岛
  3. 乌鲁木齐
- ▲ 办公室 (常驻工程师)
  4. 重庆
  5. 昆明
  6. 武汉
  7. 厦门
  7. 呼和浩特
- 售后服务中心
  9. 上海
  10. 广州
  11. 重庆
  12. 天津 (在建中)

**北方销售分公司**  
• 位于北京市  
• 业务覆盖北京、天津、黑龙江、吉林、辽宁、内蒙古、河北、山西、山东各省市地区。

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**华东销售分公司**  
• 位于上海市  
• 业务覆盖上海、河南、湖北、安徽、江苏、浙江、江西各省市地区。



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# 凯士比中国 - 泵：上海凯士比泵提供一流产品

KSB 已成为中国提供先进泵类产品之最重要供应商

## 产品链



Movitec



Amacan



Amarex KRT



SEZ



Omega



RDL/O



HG



CHTC



Magnochem



Etanorm



CPK/N



HPKL

# KSB 中国 - 泵: 适用行业

清水

污水

工业

能源

楼宇



## 应用领域

- 取水
- 脱盐
- 水处理
- 水运输
- 灌溉
- 废水处理
- 污水泵站
- 雨水泵站
- 基础工业
- 流程工艺
- 热水运送
- 化工/石化
- 航运
- 燃料电站
- 联合循环电站
- 核电站
- 可再生能源
- 楼宇供水/排水
- 卫生设备
- 供暖
- 通风空调系统

# Contents

- Introduction
- Impeller & guide vane design
- Optimization in CAESES
- Conclusion



# Impeller and guide vane design

## 设计参数

	单位	参数值	备注
流量 $Q_{opt}$	$m^3/h$	550	
扬程	m	40~45	
效率	%	84.7%	达到GB 19762-2007 单级单吸清水离心泵节能要求值
转速	rpm	1480	
介质		常温清水	

## 结构设计要求

参数	单位	叶轮	导叶
结构形式		闭式离心式叶轮	空间导叶形式
轴孔直径 $dk$	mm	$\geq 80$	$\geq 115$
轮毂直径	mm	$\geq 95$	$\geq 130$
叶片数		5或7	7~9



# Impeller and guide vane design

## 设计参数

	单位	参数值	备注
流量 $Q_{opt}$	$m^3/h$	550/500	
扬程	m	40~45/33~35	
效率	%	84.7%	达到GB 19762-2007 单级单吸清水离心泵节能要求值
转速	rpm	1480	
介质		常温清水	

## 结构设计要求



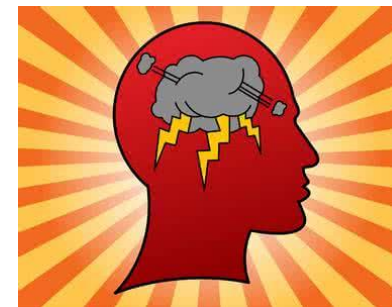
参数	单位	叶轮	导叶
结构形式		闭式离心式叶轮	空间导叶形式
轴孔直径 $dk$	mm	$\geq 80$	$\geq 115$
轮毂直径	mm	$\geq 95$	$\geq 130$
叶片数		5或7	7~9



# Impeller and guide vane design

- 参考模型：公司原有的水力模型
- 设计软件：内部软件
- 建模软件：UG
- 优化软件：CAESES
- 模拟软件：CFX18.0

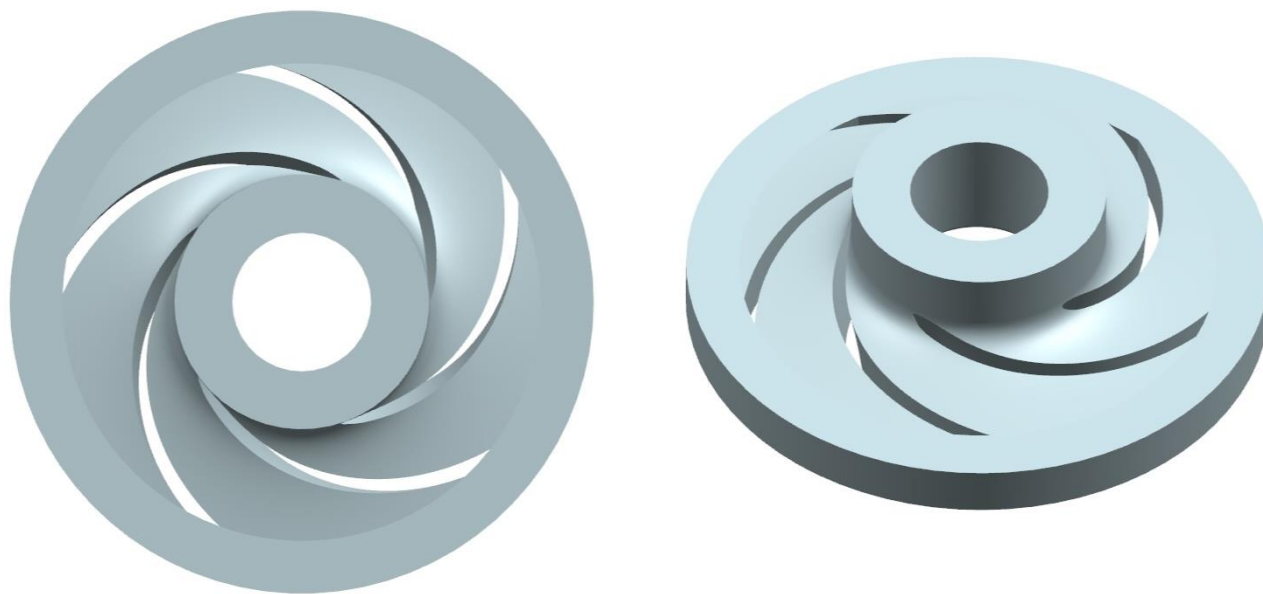
## 开发流程



1. 参考已有的水力模型设计叶轮
2. 凡方软件设计空间导叶
3. UG软件将叶轮和导叶装配为级泵
4. CFX数值模拟，预测水泵性能，分析流场结构
5. 根据分析结果重复上述4步，直到满足设计要求。

# Impeller design and simulation

水泵扬程要在40-45m之间，因此初步设计叶轮扬程为45m

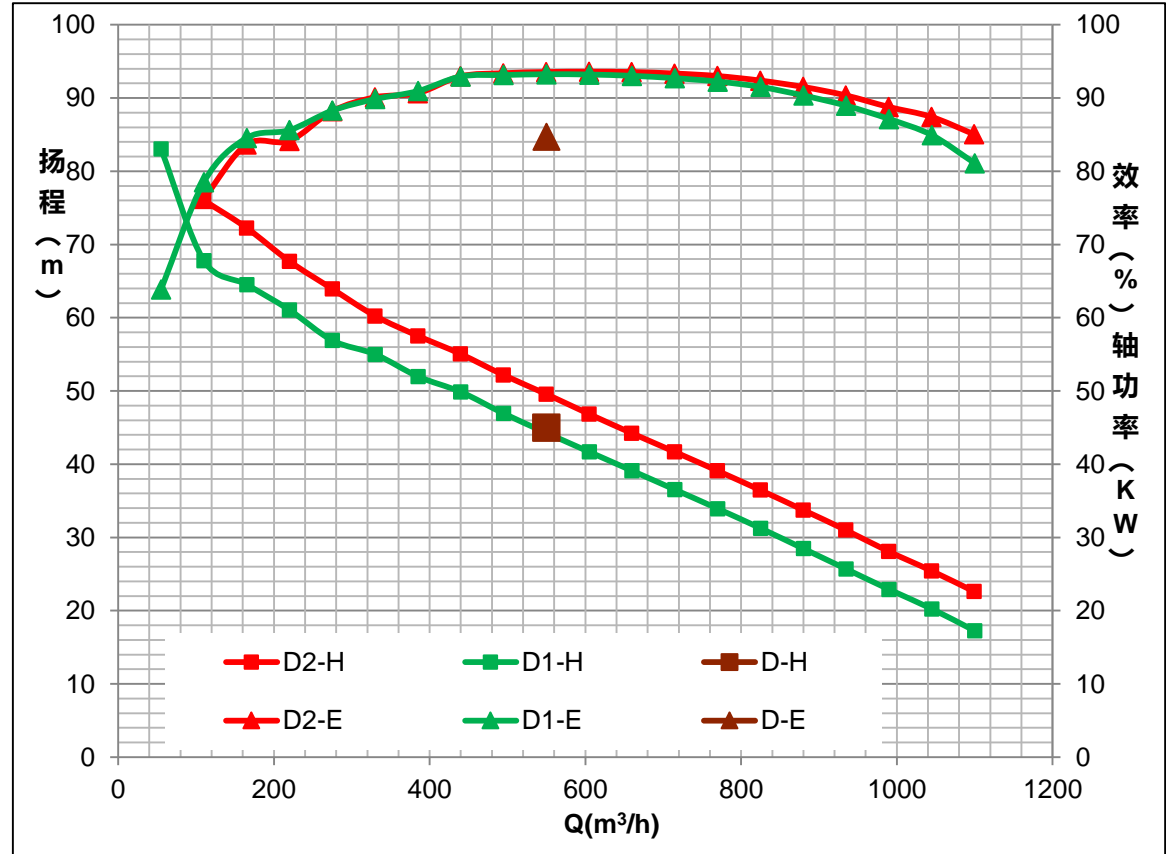


	比转速 $N_s$	叶轮外径 $D_2$ (mm)	进口直径 $D_j$ (mm)	轮毂直径 $D_h$ (mm)	叶片数 $z$	叶片包角 $\phi$ ( $^\circ$ )	出口宽度 $b$ (mm)	出口角 $\beta_2$ ( $^\circ$ )
D1	121.5	402.7	214.4	116.8	5	93	42	22.5
D2	121.5	389	212.1	113	5	93	44.5	22.5



# Impeller and guide vane design

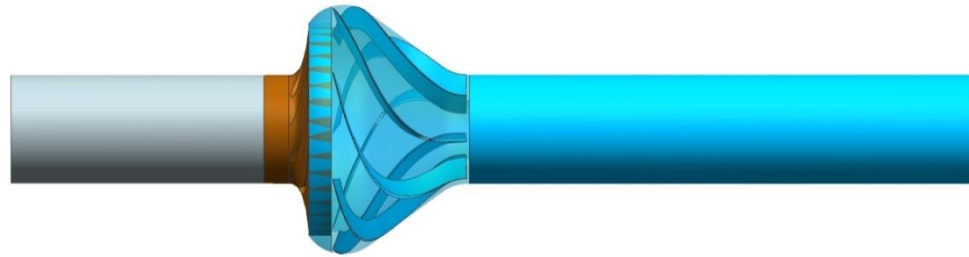
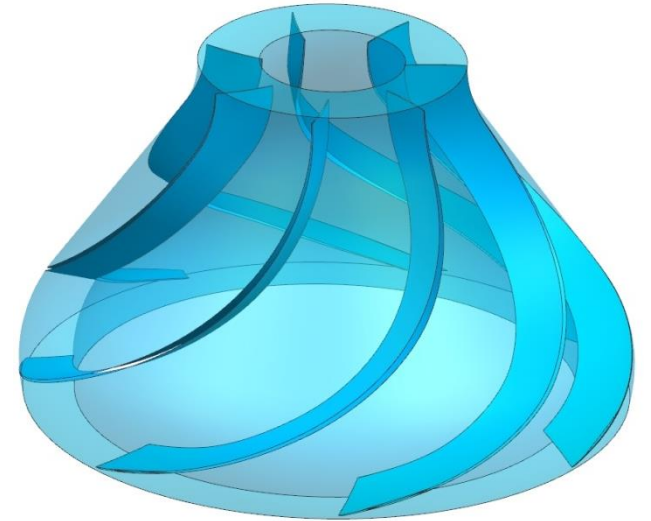
水泵扬程要在40-45m之间，因此初步设计叶轮扬程为45m



# Impeller and guide vane design

## IMP2+Diff1

	叶轮外径 $D_2$ (mm)	进口直径 $D_j$ (mm)	出口轮毂 直径 $D_h$	叶片数 $z$
Diff1	214.4	489	116.8	7



# Impeller and guide vane design

## IMP2+Diff1

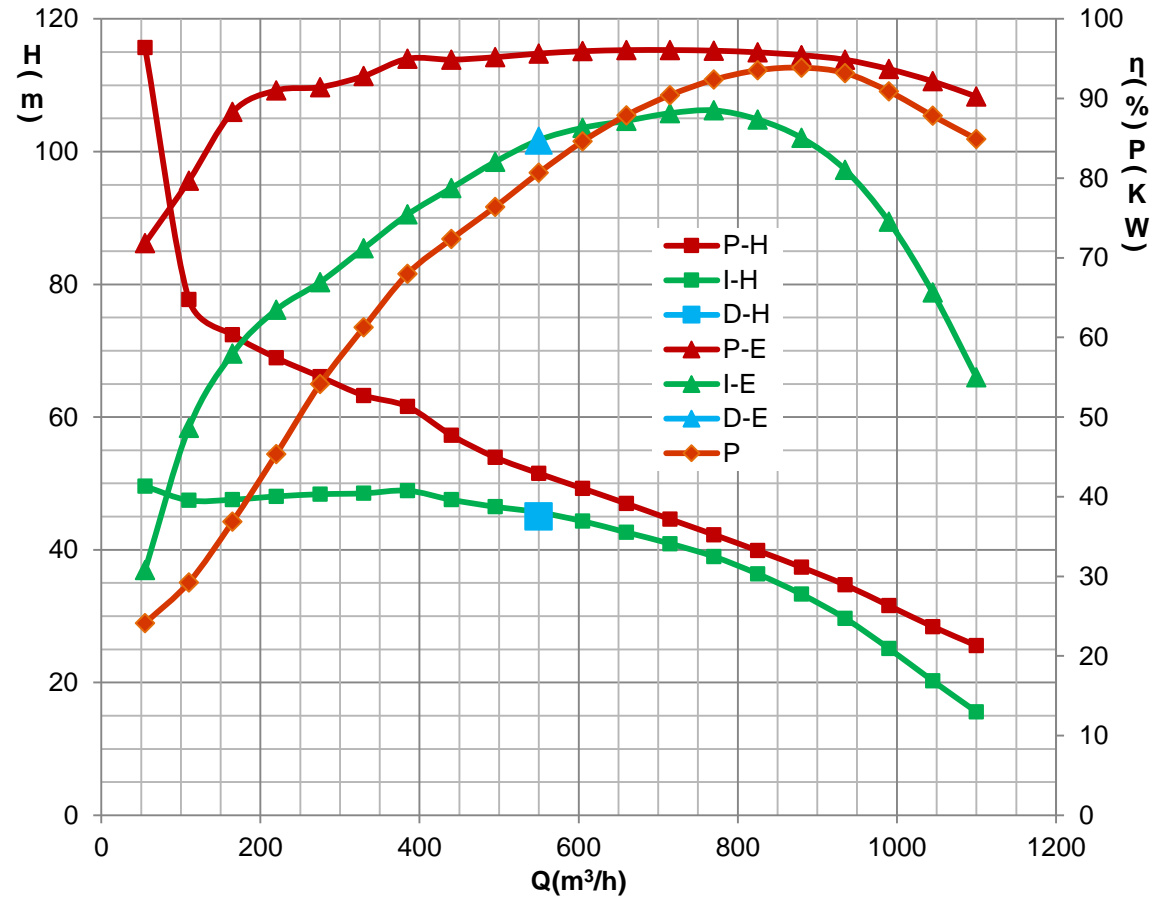
出口流量 (m <sup>3</sup> /h)	水泵扬程 (m)	水泵效率 (%)	轴功率 (KW)	叶轮扬程 (m)	叶轮效率 (%)
55	49.57	30.78	24	115.70	71.84
110	47.45	48.65	29	77.72	79.68
165	47.56	57.98	37	72.43	88.31
220	48.05	63.48	45	68.92	91.03
275	48.38	66.94	54	66.08	91.43
330	48.51	71.19	61	63.26	92.83
385	48.91	75.44	68	61.58	95.00
440	47.54	78.76	72	57.27	94.88
495	46.49	82.05	76	53.94	95.19
550	45.65	84.78	81	51.51	95.65
605	44.31	86.32	85	49.25	95.94
660	42.63	87.21	88	46.97	96.08
715	40.93	88.16	90	44.61	96.09
770	38.98	88.51	92	42.28	96.01
825	36.37	87.37	94	39.88	95.80
880	33.31	85.06	94	37.38	95.45
935	29.66	81.05	93	34.71	94.87
990	25.12	74.54	91	31.58	93.70
1045	20.26	65.65	88	28.43	92.16
1100	15.58	54.99	85	25.57	90.24





# Impeller and guide vane design

## IMP2+Diff1

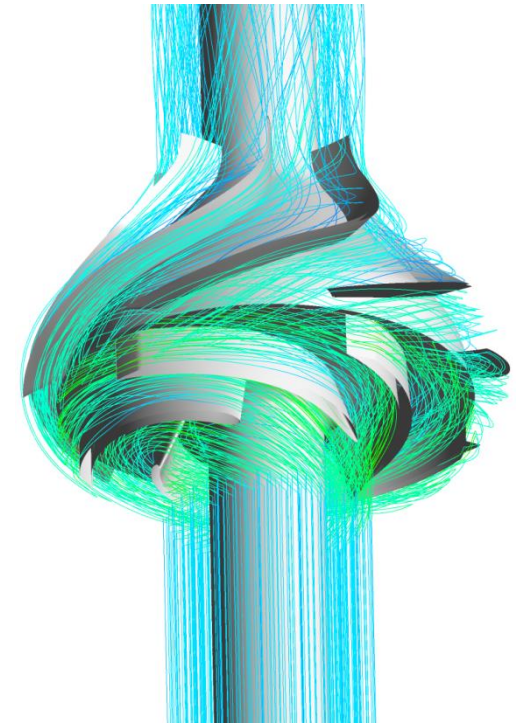
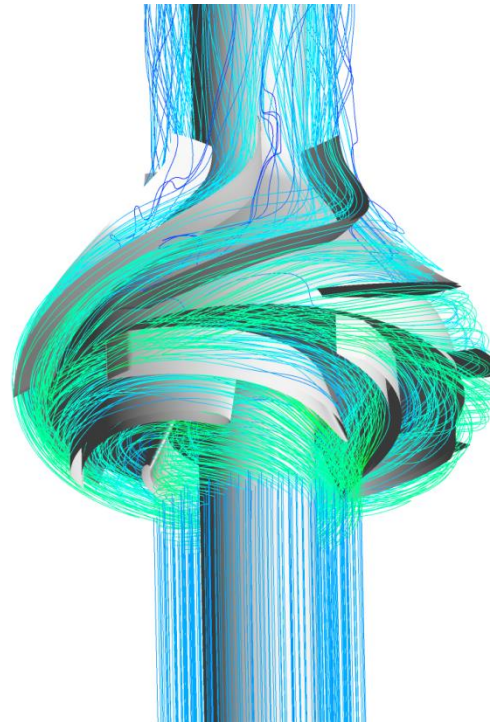


# Impeller and guide vane design

**IMP2+Diff1**

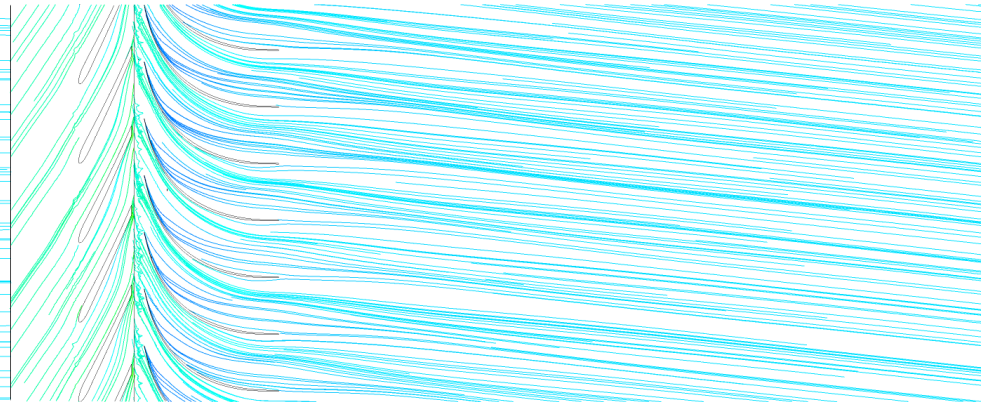
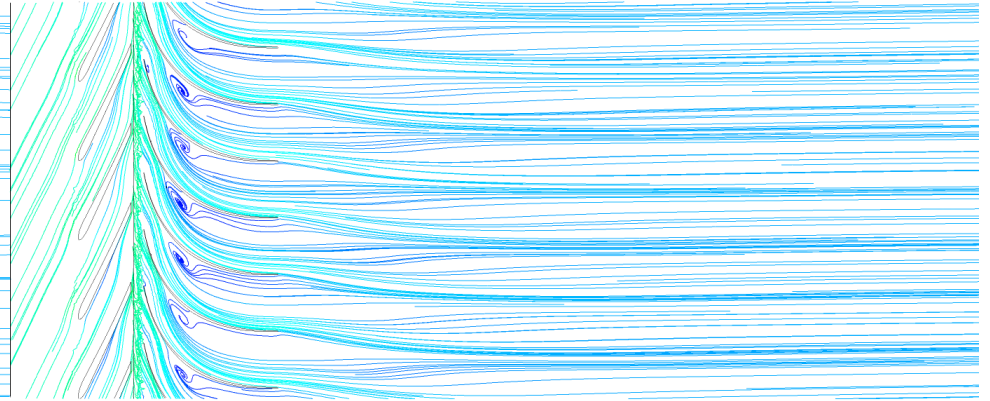
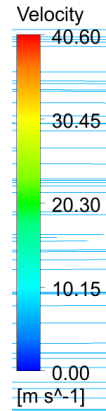


Velocity  
40.60  
30.45  
20.30  
10.15  
0.00  
[m s<sup>-1</sup>]



# Impeller and guide vane design

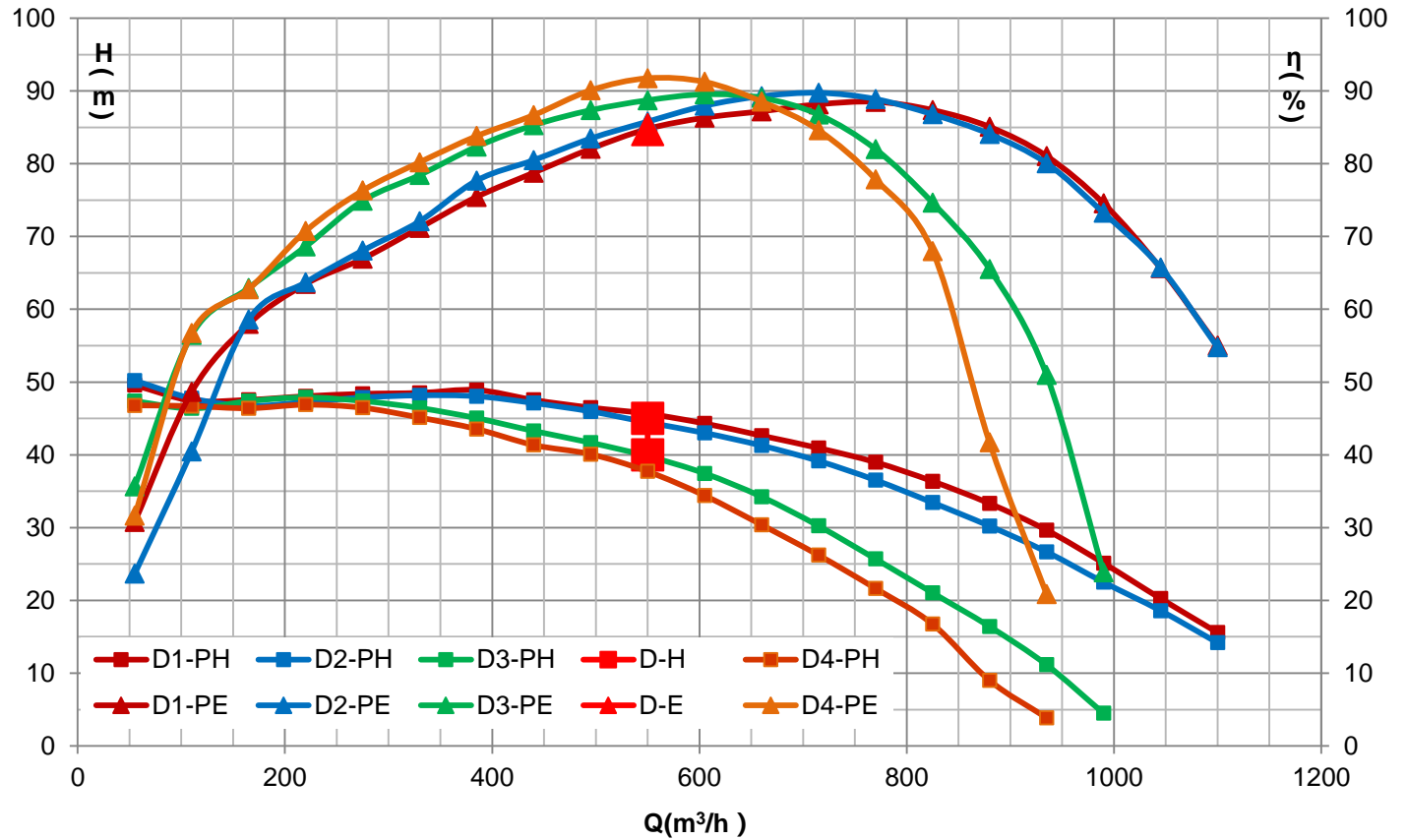
## IMP2+Diff1





# Impeller and guide vane design

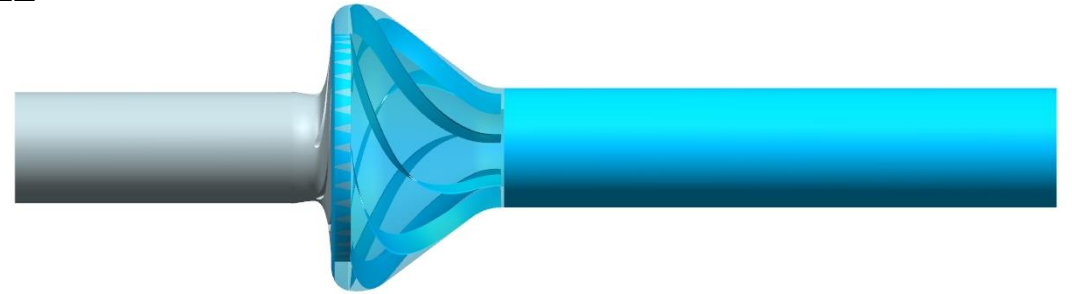
## IMP3+Diff3



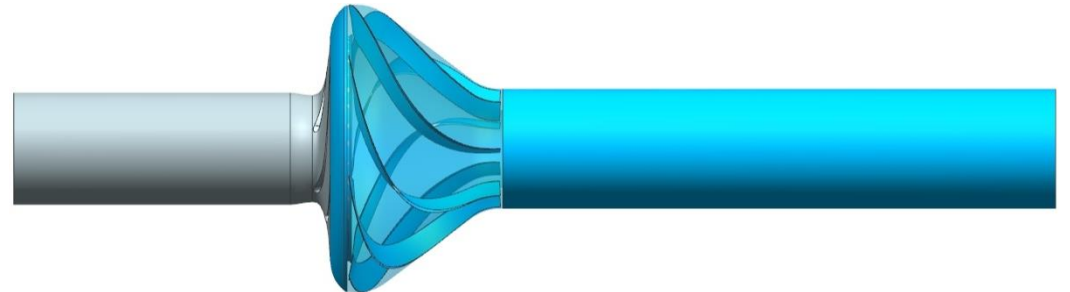
# Impeller and guide vane design

新开发的空导叶式离心泵满足设计要求，即性能满足设计要求，结构满足设计要求。其中第三种模型满足设计要求，第四种模型高效，扬程还需进一步提高。

**IMP3+Diff2**



**IMP3+Diff3**



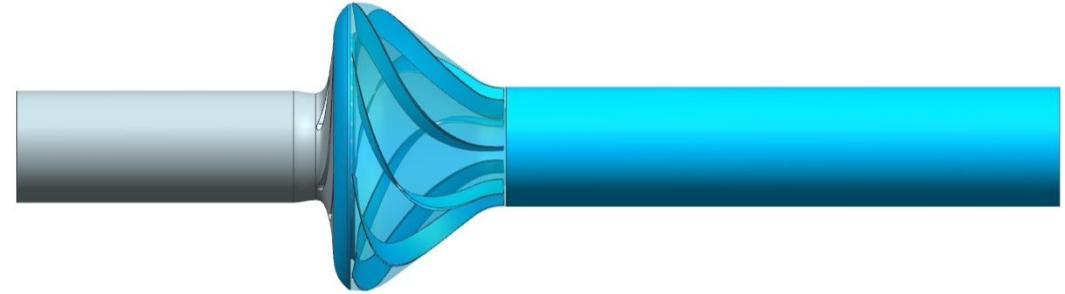
# Impeller and guide vane design

1. 利用软件可以快速得到性能优异的水力模型
2. 关老师软件存在诸多经验参数，需要慎重选择
3. 设计-模拟-分析-再设计的开发流程繁复
4. 泵结构参数多，参数对性能的影响程度
5. 水泵参数化建模，计算机硬件水平



# Optimization in CAESES

IMP3+Diff3



**How to optimize?**

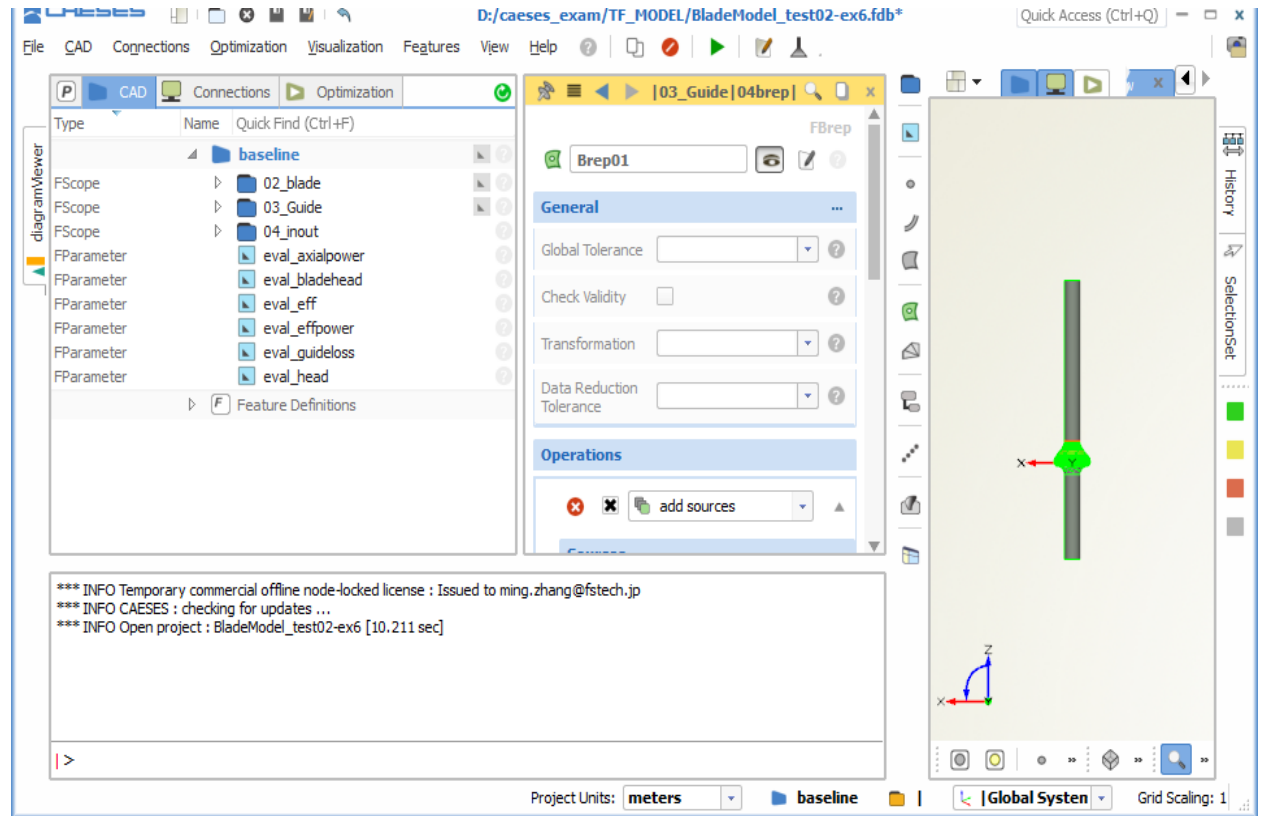
**Manual & software**

**Parametric modeling for the blades & vanes**



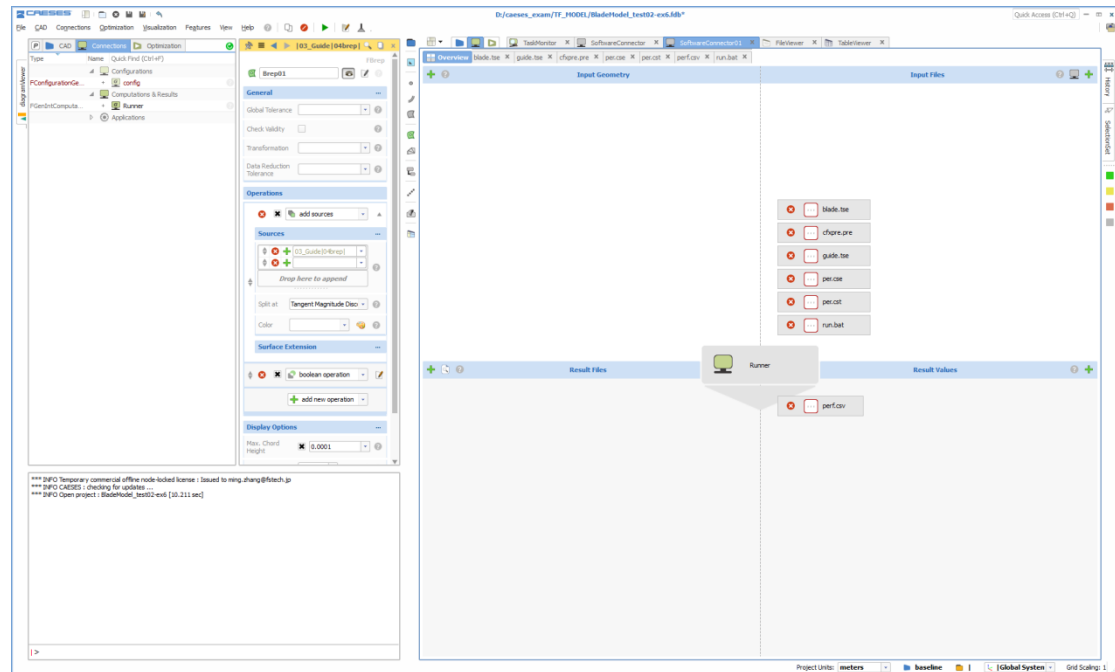
# Optimization in CAESES

## CAESES



# Optimization in CAESES

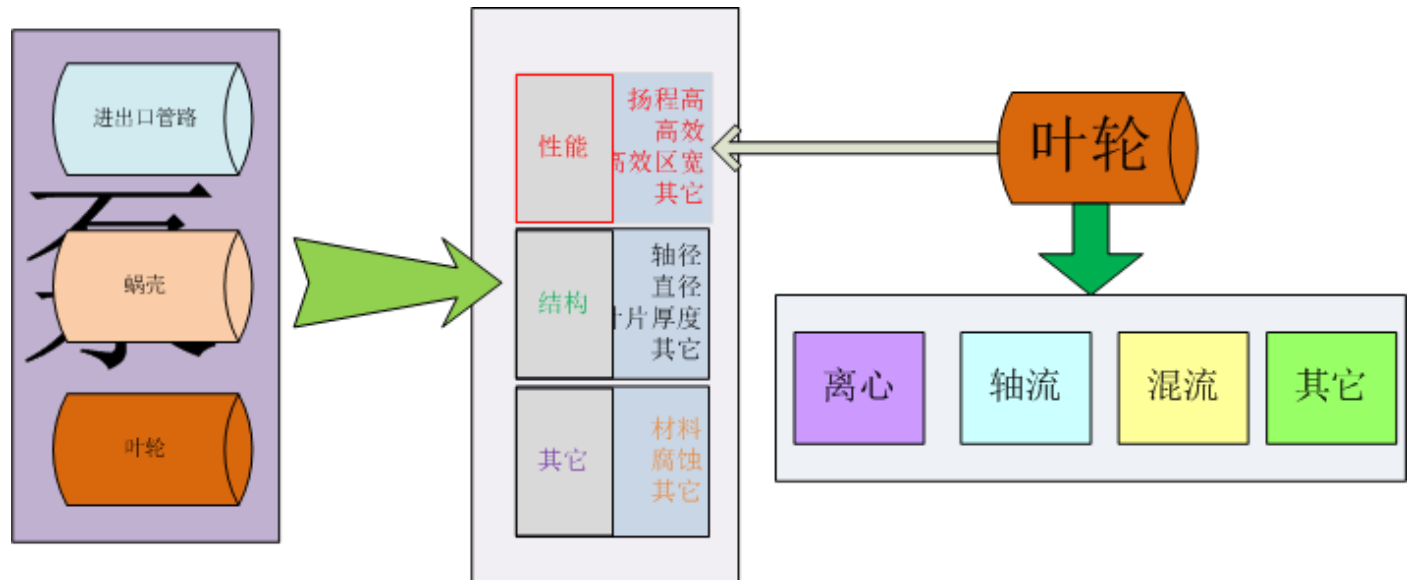
## CAESES





# Optimization in CAESES

Parametric modeling for the blades & vanes



### 叶轮主要几何参数

汽蚀性能

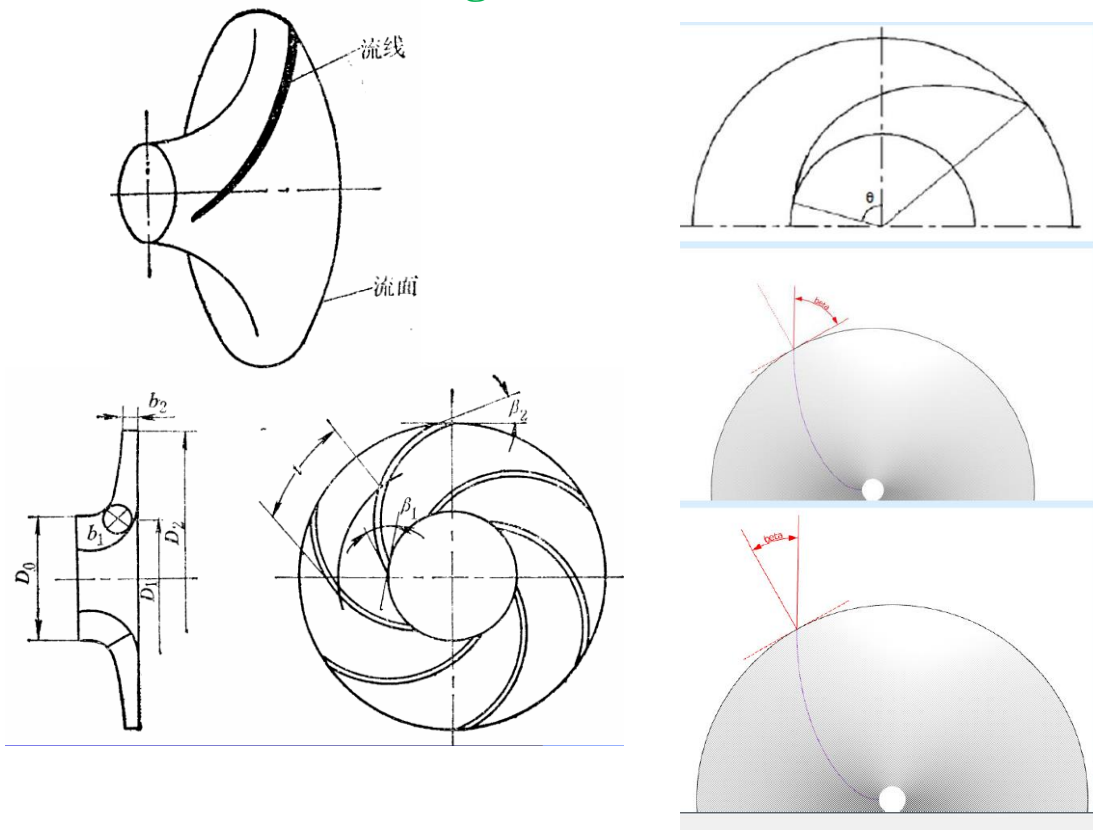
性能

效率

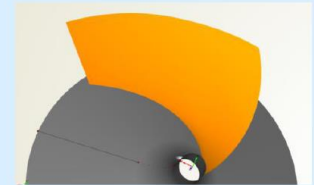
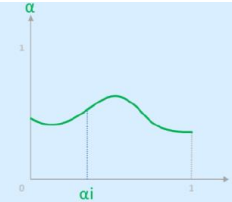
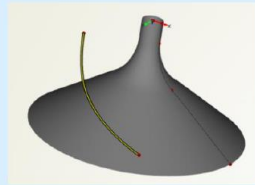
- 叶轮进口直径  $D_j$
- 叶片进口直径  $D_1$
- 叶轮轮毂直径  $d_h$
- 叶片进口宽度  $b_1$
- 叶片进口角  $\beta_1$
- 叶轮出口直径  $D_2$
- 叶轮出口宽度  $b_2$
- 叶片出口角度  $\beta_2$
- 叶片数  $z$
- 叶片包角  $\phi$

现代泵技术手册, P187

### Parametric modeling for the blades & vanes



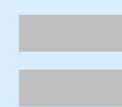
# Optimization in CAESES



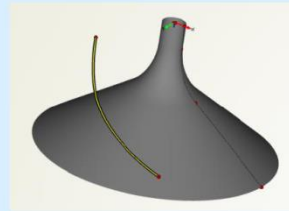
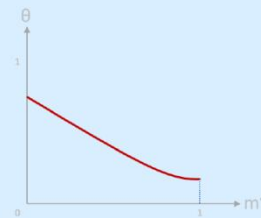
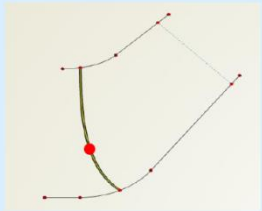
Stream Section



Distributions



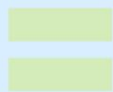
Camber Surface



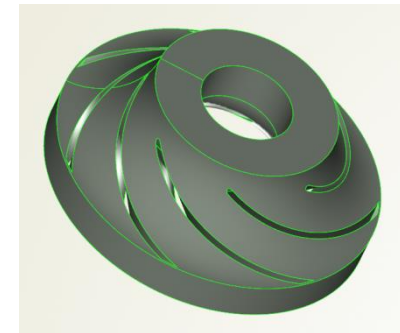
Hub and Shroud Stacking Axis Radius



Mean Camber Definition



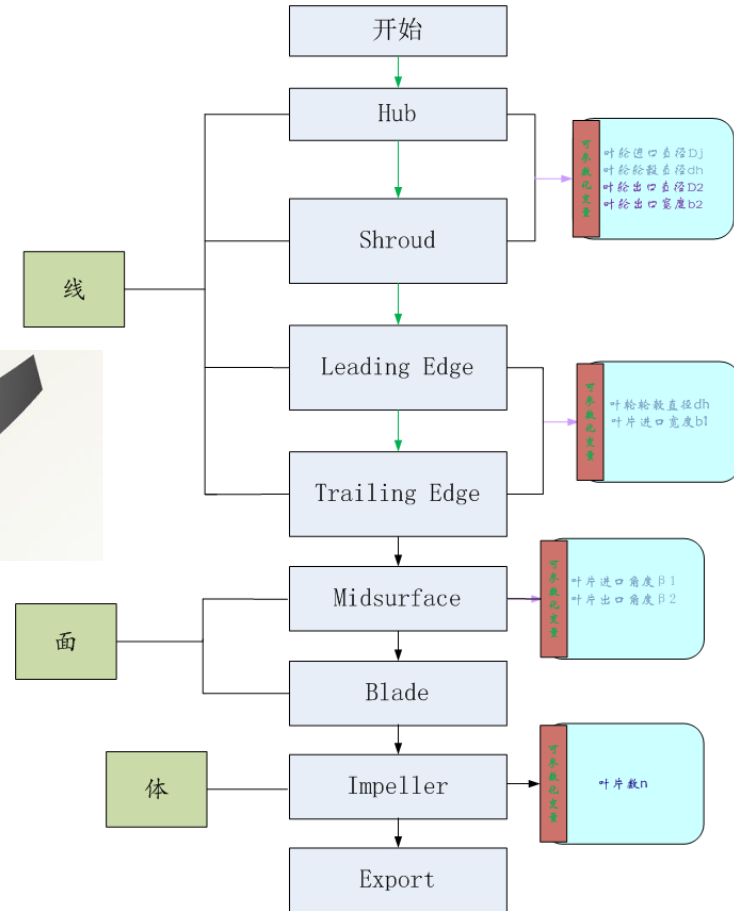
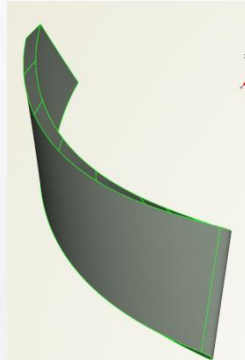
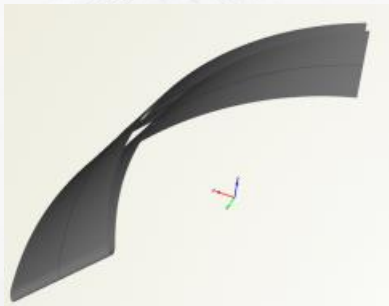
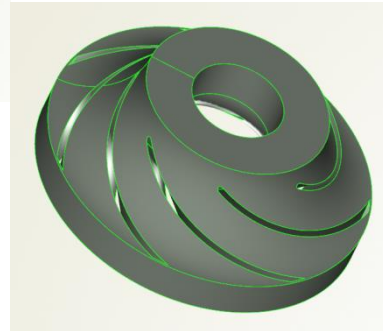
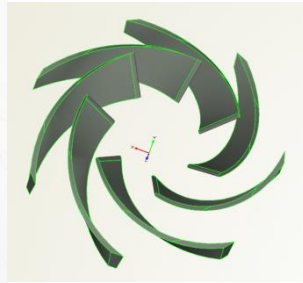
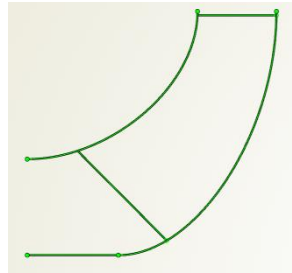
3D Stream Section



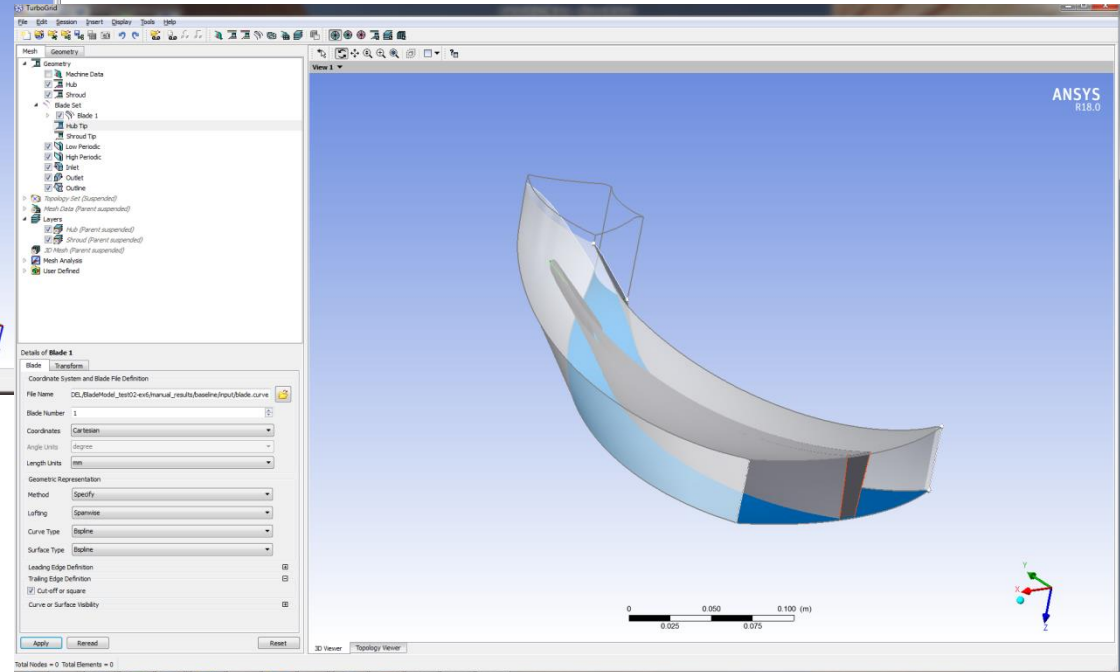
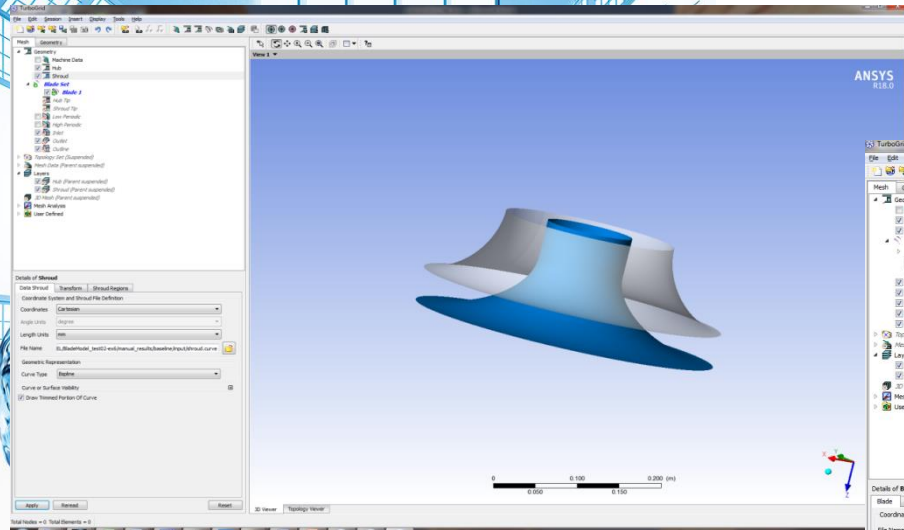


# Optimization in CAESES

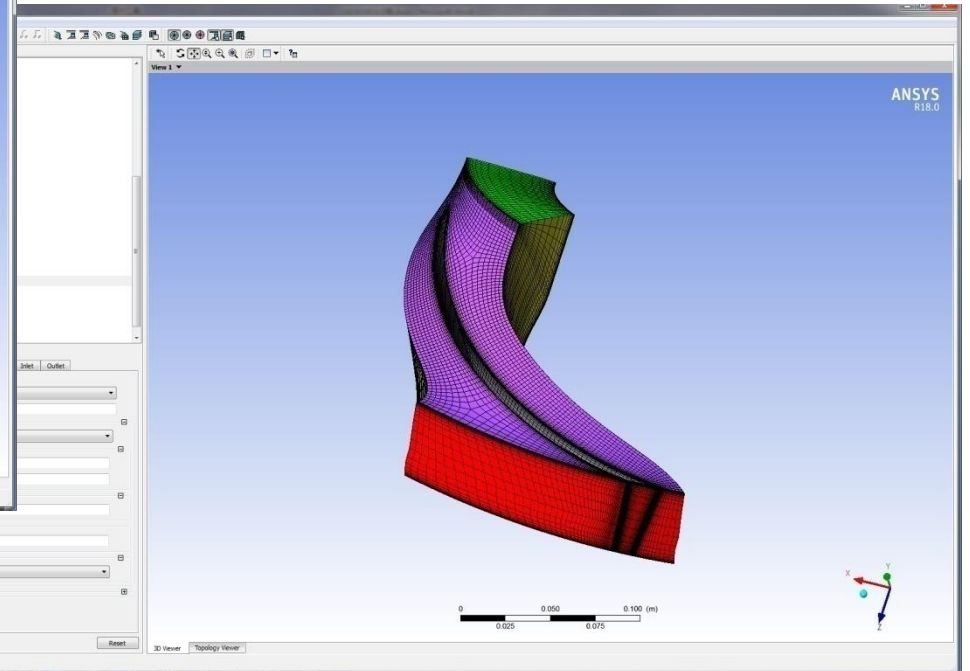
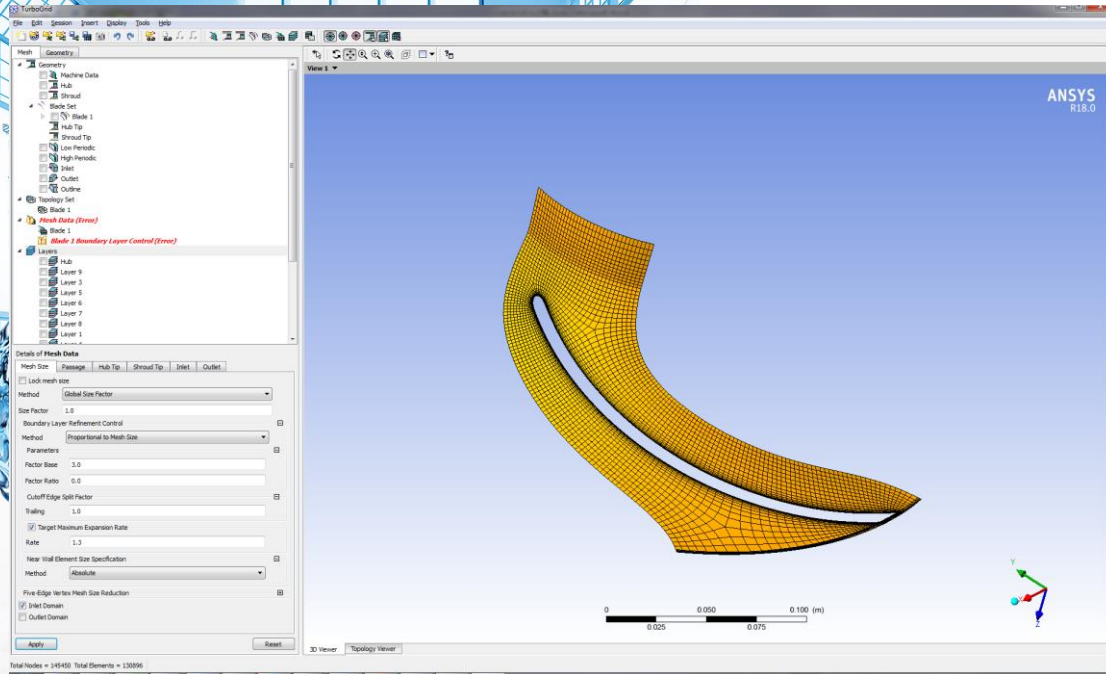
## Parametric modeling of the blades & vanes



# Optimization in CAESES

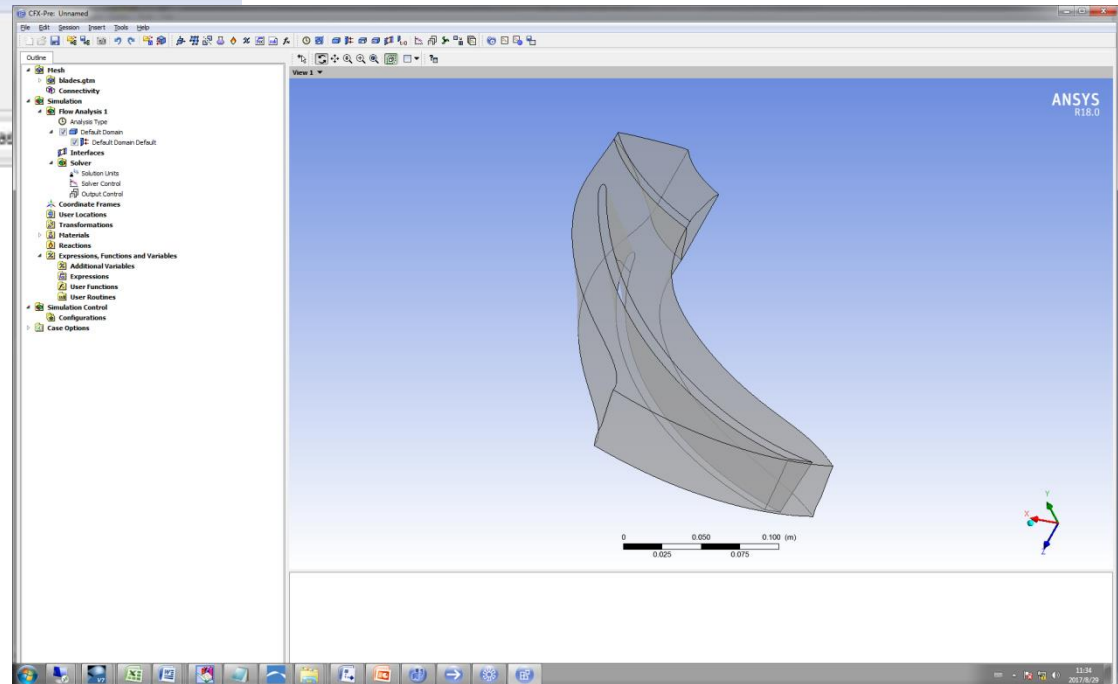


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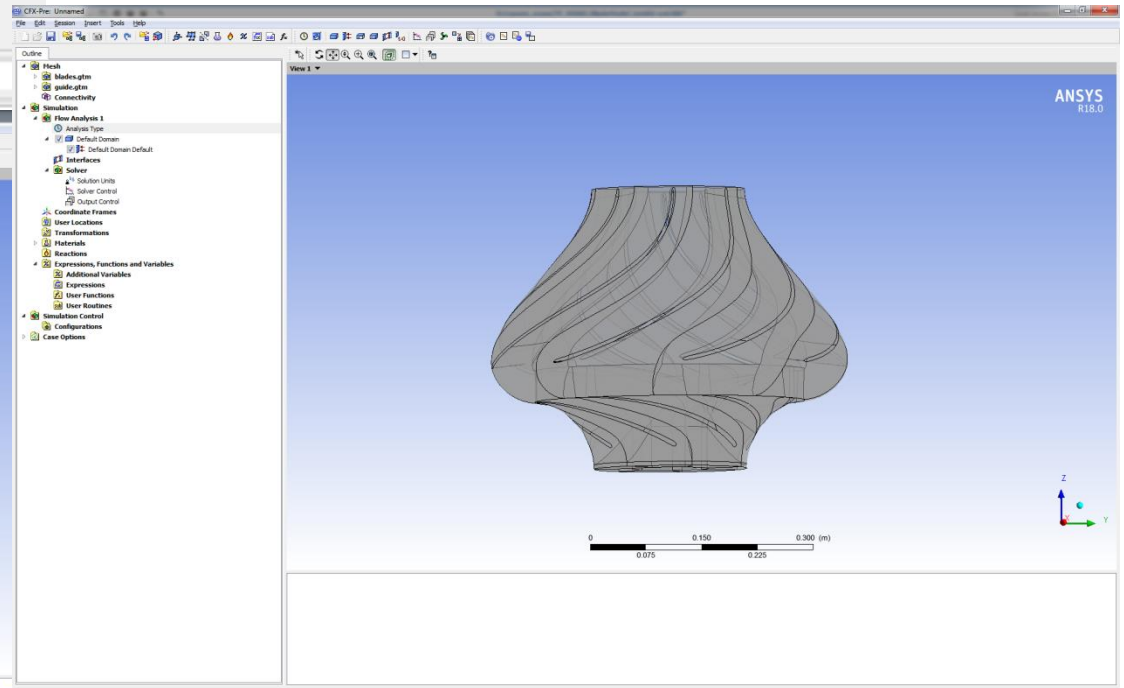
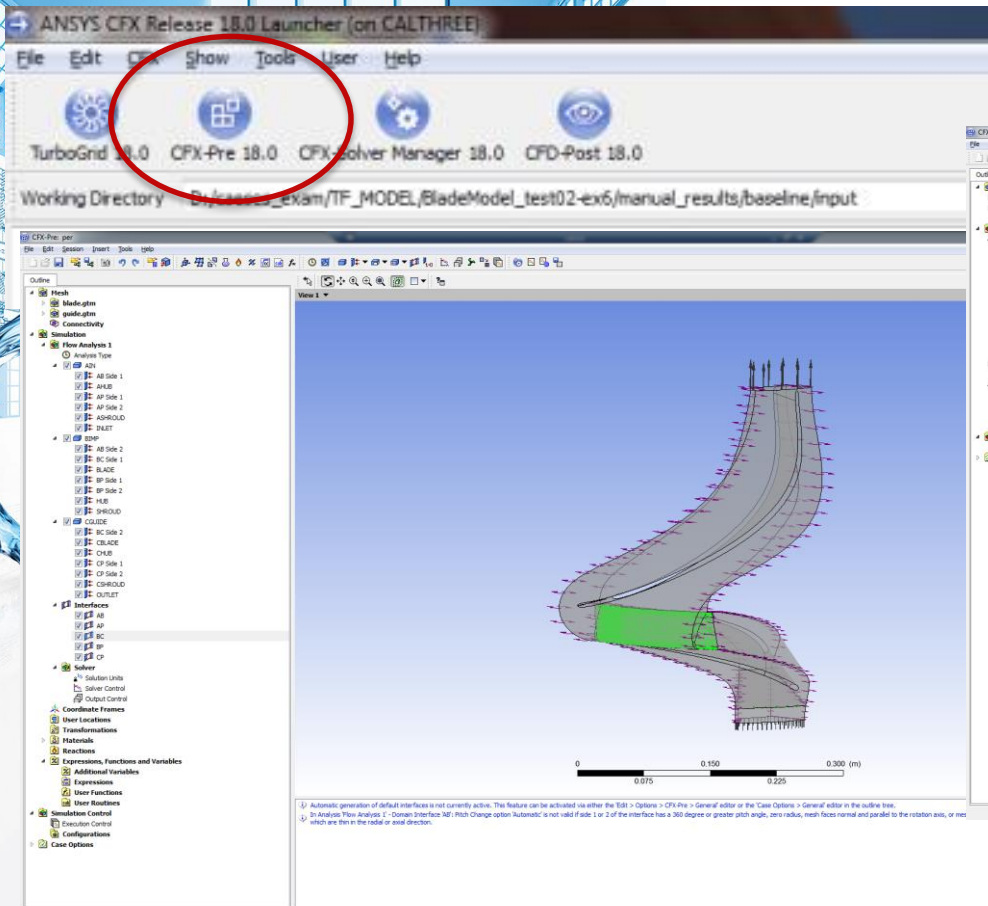




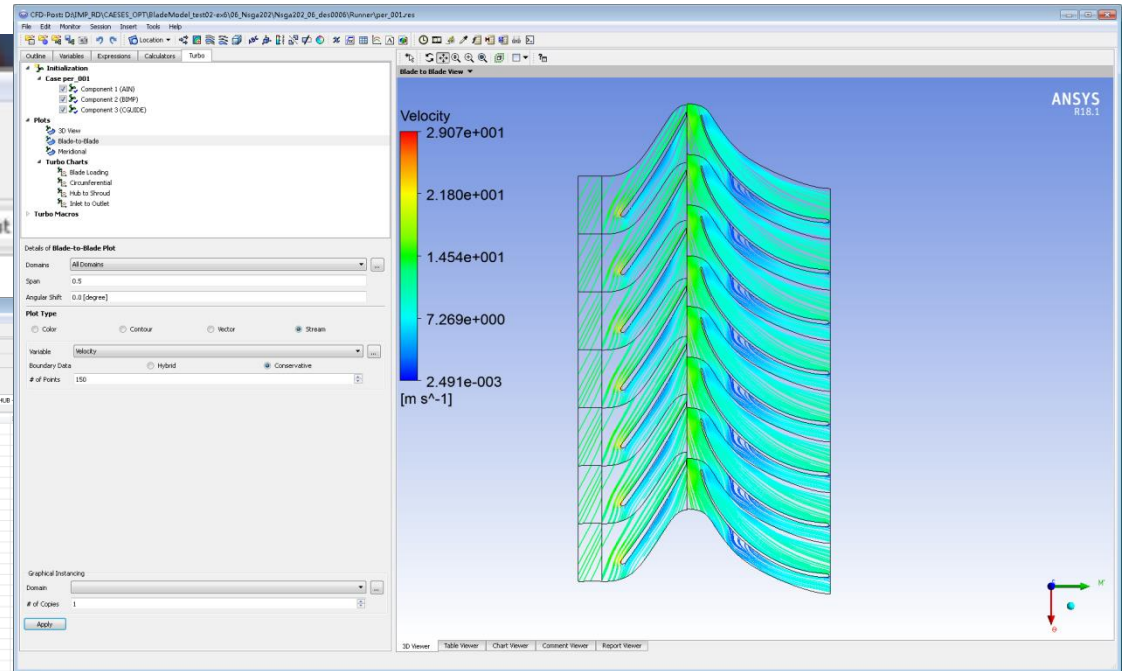
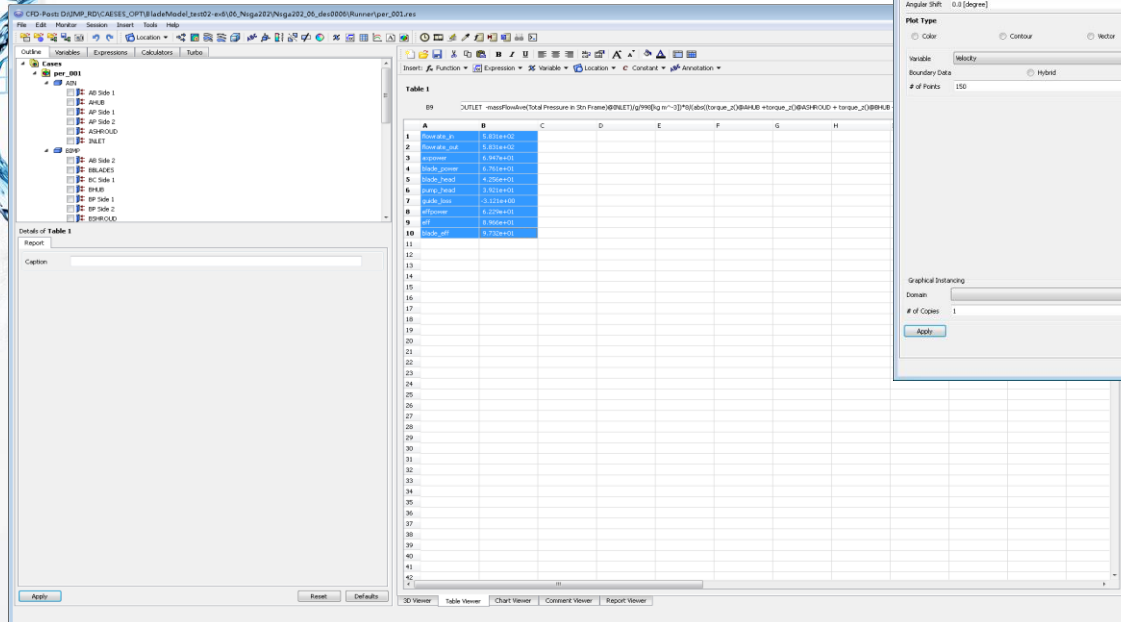
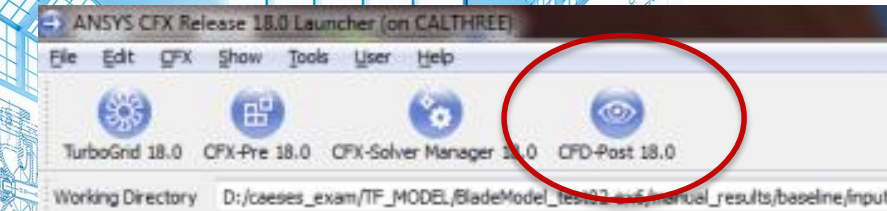
# Optimization in CAESES



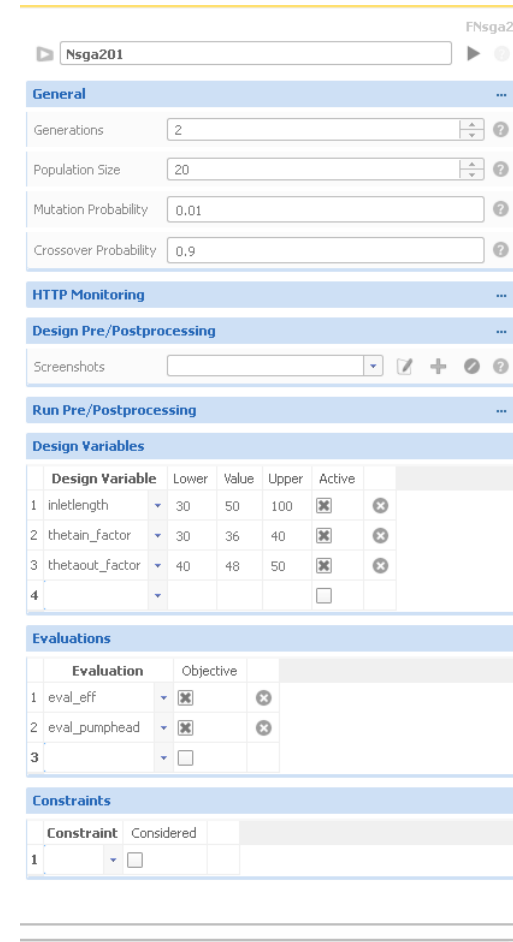
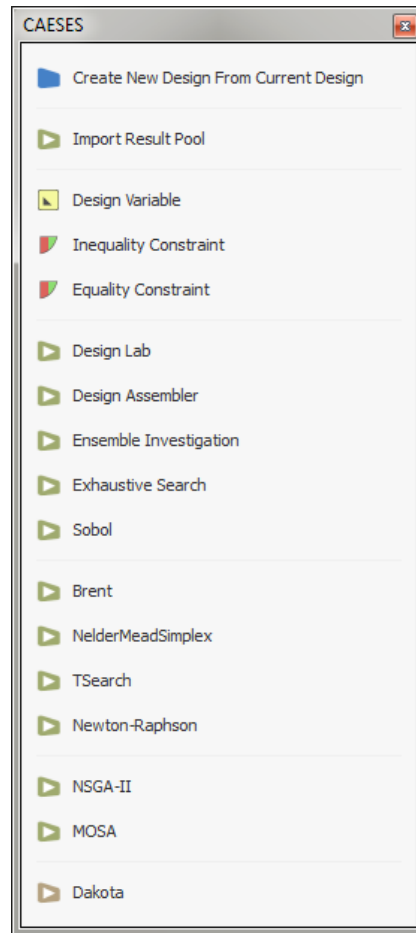
# Optimization in CAESES



# Optimization in CAESES

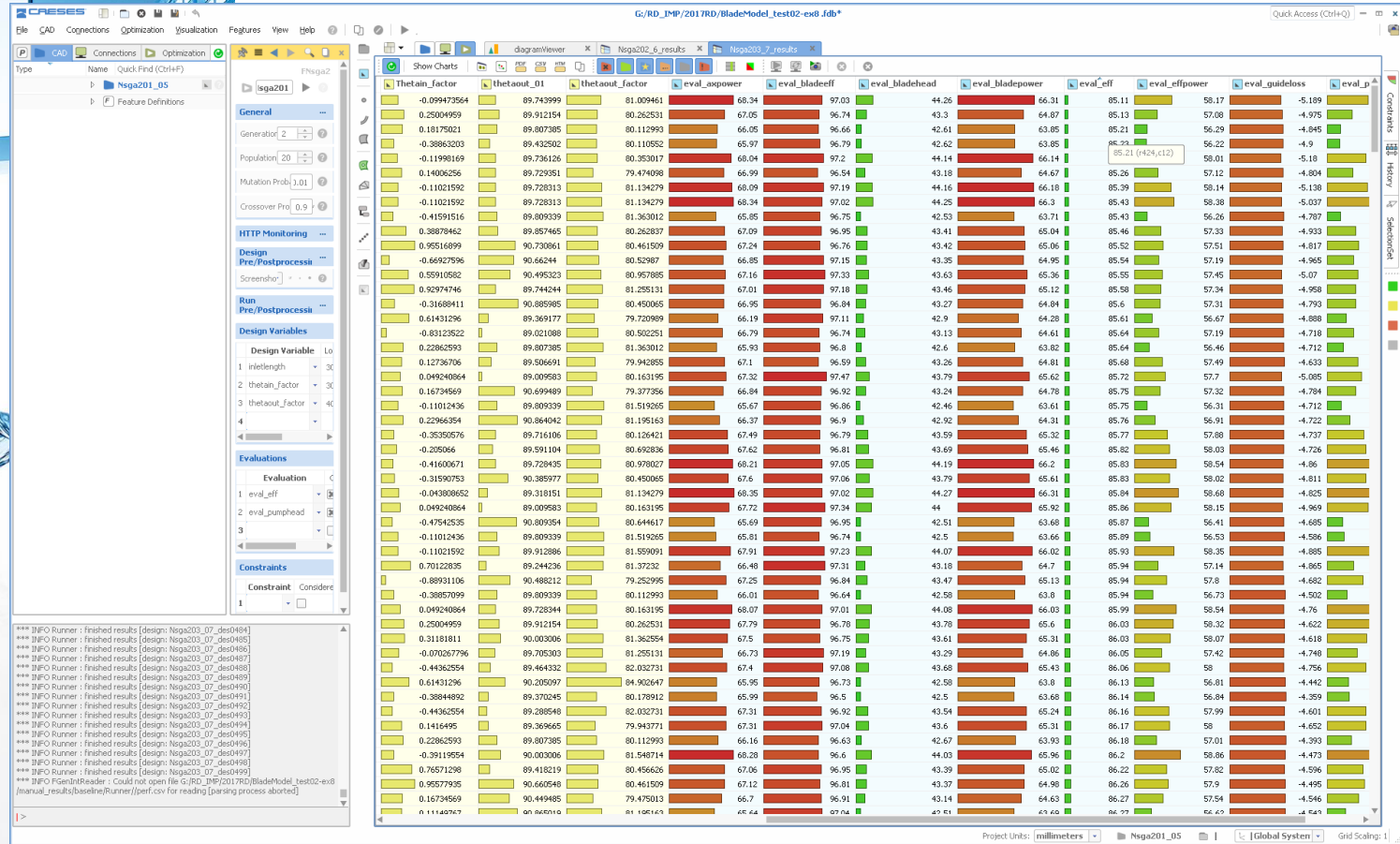


# Optimization in CAESES

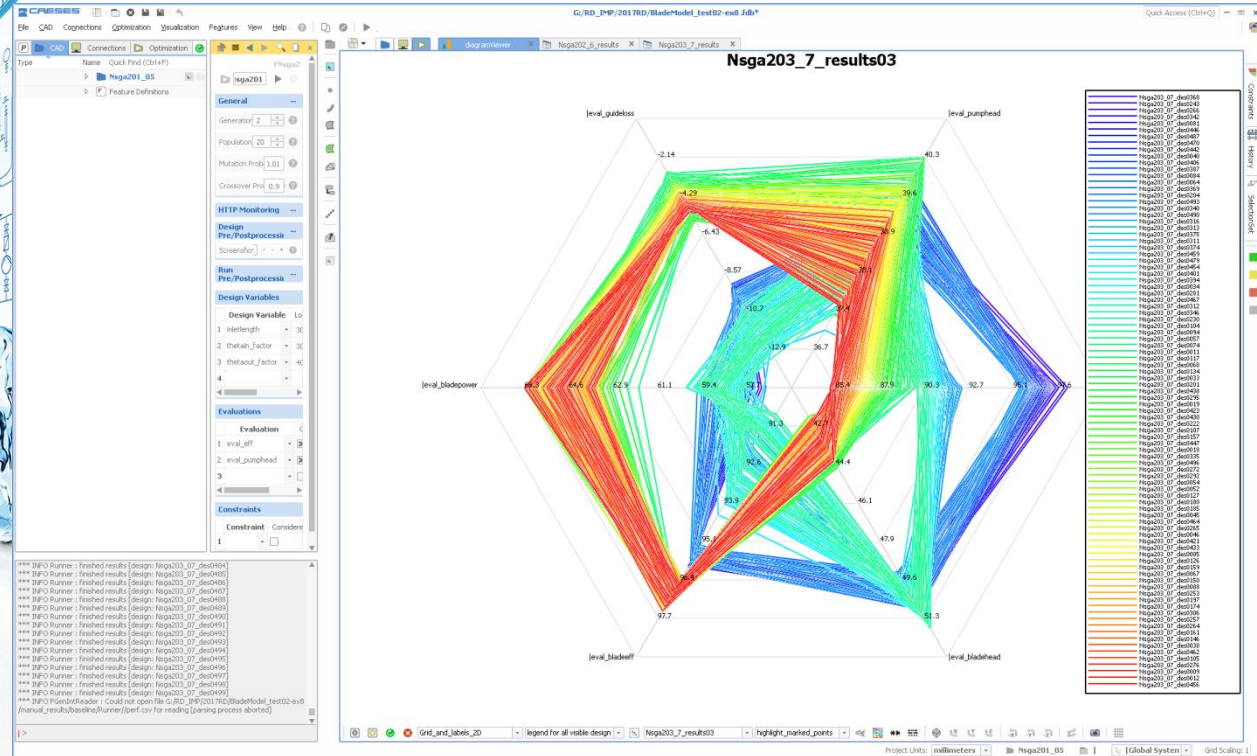




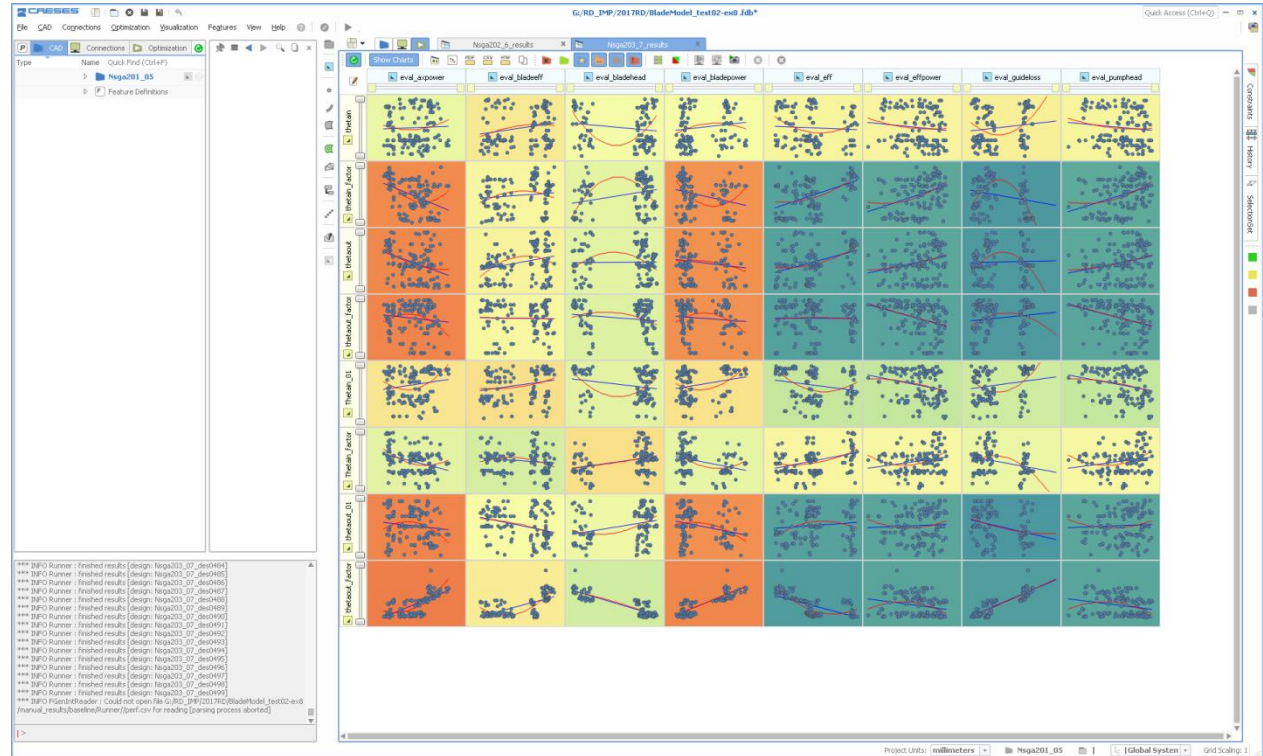
# Optimization in CAESES



# Optimization in CAESES

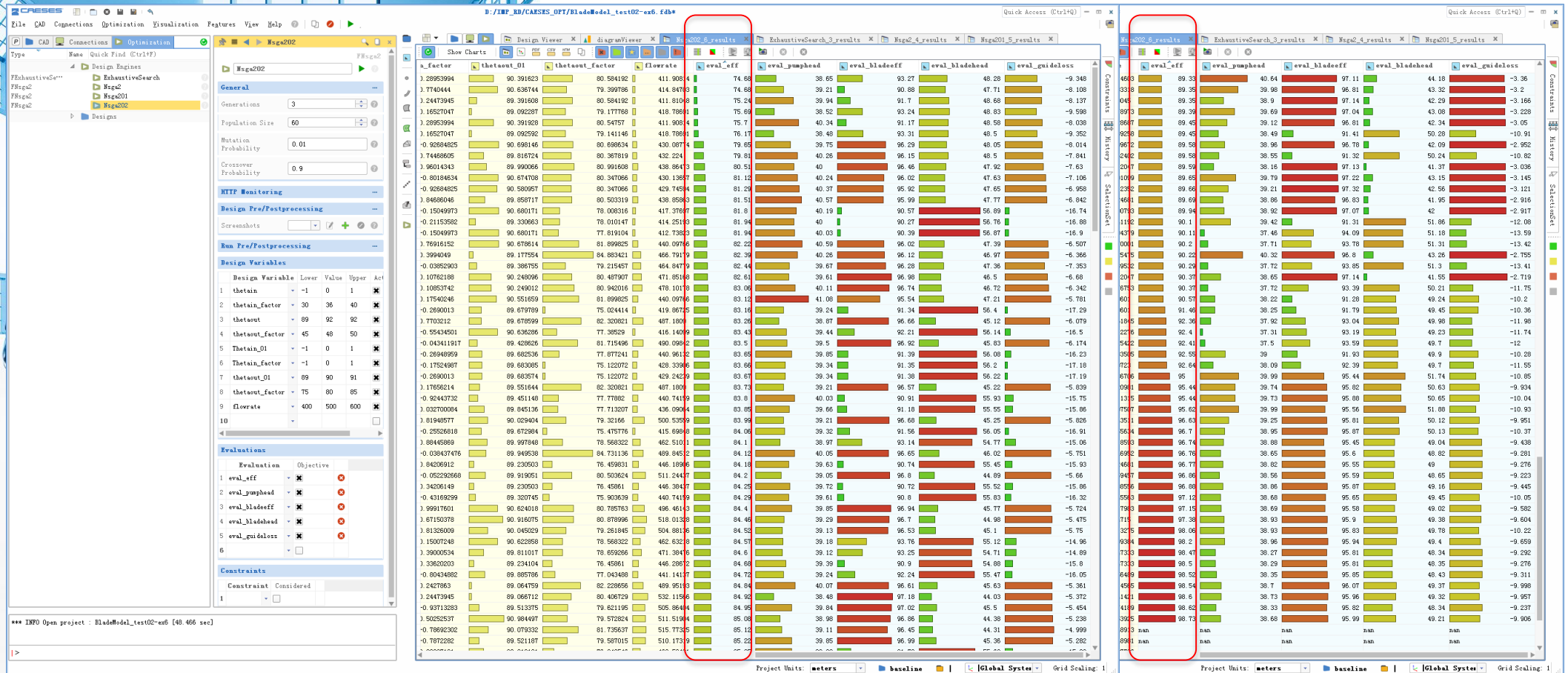


# Optimization in CAESES





# Optimization in CAESES





# Optimization in CAESSES

The screenshot displays the CAESSES software interface for an optimization project. On the left, the 'Optimization' panel shows settings for the 'Hsga202' engine, including Generations (3), Population Size (60), Mutation Probability (0.01), and Crossover Probability (0.9). Below this, 'Design Variables' are listed with their lower, value, and upper bounds, and 'Evaluations' are tracked with checkboxes for each objective.

The main window shows a 'Results' table with columns for various design parameters and objective functions. A red box highlights the top-performing solutions. The table data is as follows:

ID	a_factor	thetaout_01	thetaout_factor	flowrate	eval_eff	eval_pumphead	eval_bladeeff	eval_bladehead	eval_guideloss
-0.84786755	90.520226	83.336851	510.17829	86.91	40.31	96.99	44.99	-4.497	
0.93954376	90.230823	84.731441	489.94583	86.6	41.34	96.42	46.02	-4.484	
-0.93655299	90.449516	83.526131	523.83307	86.66	39.57	96.8	44.2	-4.449	
0.46019694	89.240055	80.409729	538.36576	86.68	39.03	96.8	43.58	-4.367	
-0.002853071	89.251328	80.821622	518.00711	87.03	39.5	96.29	44	-4.356	
-0.3192637	90.445809	83.491951	523.95514	87.01	39.69	96.86	44.18	-4.319	
-0.44527362	90.736934	81.96376	529.33242	87.19	39.55	97.01	44	-4.28	
-0.79473584	89.26804	81.738079	573.196	86.97	37.75	97.05	42.12	-4.173	
0.085343709	89.136141	82.862211	543.61486	87.5	40	97.12	44.39	-4.172	
0.20527962	90.048936	81.737621	572.12177	87.07	37.74	97.14	42.1	-4.172	
0.82455177	89.647593	82.362478	524.75776	87.57	40.41	96.86	44.69	-4.092	
-0.46089876	90.736934	81.968643	529.32631	87.45	39.63	96.78	44.08	-4.029	
-0.91461051	89.386145	82.87808	541.27108	87.8	39.95	97.05	44.15	-3.991	
-0.061722744	89.78234	81.259098	574.44114	87.56	38.63	97.14	42.85	-3.981	
-0.055497063	89.776715	81.509346	574.73411	87.61	38.87	97.1	42.98	-3.863	
-0.56697948	89.804364	82.011521	552.96866	87.92	39.62	96.98	43.69	-3.862	
-0.79473584	89.102595	81.738079	573.196	87.11	37.98	96.98	42	-3.824	
-0.58722362	89.849042	82.011521	556.38056	88.09	39.67	96.99	43.67	-3.781	
-0.79473584	89.279759	81.738079	570.07095	87.66	38.32	96.82	42.32	-3.776	
-0.33580929	89.201848	84.888457	566.39353	88.07	39.17	97.03	43.15	-3.761	
0.22895541	89.738354	84.442123	568.05371	88.22	38.6	96.79	42.35	-3.547	
-0.74845609	90.724575	83.890974	540.50202	88.94	40.46	97.16	44.2	-3.522	
-0.7481651	89.230716	83.174716	540.50202	89.09	40.55	97.13	44.21	-3.457	
0.8200351	90.508507	83.298788	505.99222	89.03	41.38	96.79	44.96	-3.436	
0.19734493	89.238346	82.996786	568.93263	88.6	38.27	96.79	41.81	-3.368	
-0.24809644	89.33521	83.190555	538.14603	89.33	40.64	97.11	44.18	-3.36	
-0.24815747	89.071534	83.506752	547.78973	89.39	39.69	97.04	43.08	-3.228	
-0.33580929	89.146034	84.862281	574.56741	89.25	39.38	96.59	42.82	-3.213	
-0.60189856	89.339663	84.418103	539.33318	89.35	39.98	96.81	43.32	-3.2	
0.12471809	90.209828	80.838102	583.0022	89.38	39.9	97.14	42	-3.166	
0.54311955	90.254261	82.255055	588.01099	89.65	39.79	97.22	43.15	-3.145	
0.34413672	89.748471	82.595006	575.80224	89.28	38.9	96.9	42.22	-3.141	
0.82252232	90.917845	80.80861	583.12352	89.66	39.21	97.32	42.56	-3.121	
-0.77141985	89.238834	83.46067	569.71084	89.21	38.54	96.8	41.83	-3.109	
0.19734493	89.241154	83.094453	578.30777	89.17	38.13	96.85	41.42	-3.107	
-0.56697948	89.790692	82.340255	560.28667	89.45	39.12	96.81	42.34	-3.05	
-0.0028534371	89.917952	80.828965	583.12047	89.59	38.16	97.13	41.37	-3.036	
-0.80254826	89.455543	83.456855	573.20211	89.31	38.79	96.73	42.01	-3.011	
0.20527962	90.060655	81.737621	568.99672	89.58	38.95	96.78	42.09	-2.952	
0.20500496	89.254388	82.249255	568.0793	89.94	38.92	97.07	42	-2.917	
0.20819516	90.061509	82.191713	575.24691	89.69	38.88	96.83	41.95	-2.916	
-0.6654094	89.8097	84.558117	543.25475	90.22	40.32	96.8	43.35	-2.755	
-0.1082328	89.714824	80.821012	583.12047	90.37	38.65	97.14	41.55	-2.719	
0.19774166	90.208029	80.590065	411.12568	nan	nan	nan	nan	nan	
-0.40050395	89.930159	77.666514	442.37736	nan	nan	nan	nan	nan	
-0.16289006	89.325414	76.75555	468.2536	nan	nan	nan	nan	nan	
0.81328009	90.045029	79.071412	500.24282	nan	nan	nan	nan	nan	
0.81328009	90.162585	79.072023	504.4419	nan	nan	nan	nan	nan	
0.97732509	90.162585	79.091554	504.4419	nan	nan	nan	nan	nan	
0.1507744	90.618067	77.334783	527.48913	nan	nan	nan	nan	nan	
-0.24815747	89.085206	83.174716	540.48981	nan	nan	nan	nan	nan	
-0.39342336	89.93547	77.666514	564.25422	nan	nan	nan	nan	nan	

# Optimization in CAESES



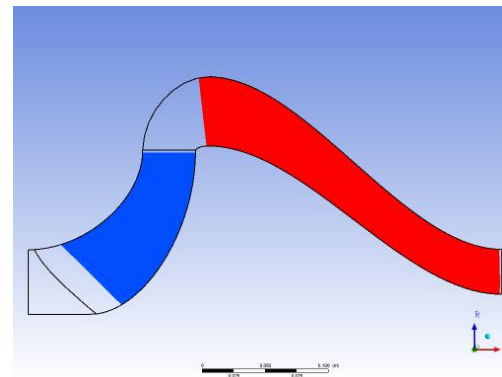
atures View Help ? | [Icons] | [Play]

Wsga202\_06\_des0112

|flowrate

Evaluations

Name	Value	Is Objective
eval_eff	90.22	Yes
eval_pumphead	40.32	Yes
eval_bladeeff	96.8	Yes
eval_bladehead	43.26	Yes
eval_guideloss	2.755	Yes



flowrate 543.255 ?

02\_blade|01\_hub

inletlength 50 ?

02\_blade|03\_LETE

t3 0.35 ?

t4 0.2 ?

02\_blade|04\_midsur|section

thetain 0.256123 ?

thetain\_factor 33.6526 ?

thetaout 91.6389 ?

thetaout\_factor 47.1211 ?

03\_Guide|02midface|variable

Thetain\_01 0.828183 ?

Thetain\_02 0 ?

Thetain\_factor -0.662409 ?

thetaout\_01 89.4907 ?

thetaout\_02 90 ?

thetaout\_factor 84.5682 ?

# Conclusions

- 水泵的参数化建模
- 采用Nsga算法对叶轮和导叶体进行了优化
- 不同参数对水泵性能的影响
- 优异的水力模型



# Questions & Comments







**Thank you  
for your  
attention!**