Improve Cooling System of the Heavy Duty Truck by KULI

FAW, Hongzhi Wang

I. J5P Cooling system with Euro 3 Emission Engine

J5P冷却系统配Euro3发动机出现过热问题

Overheat problem in the experiment

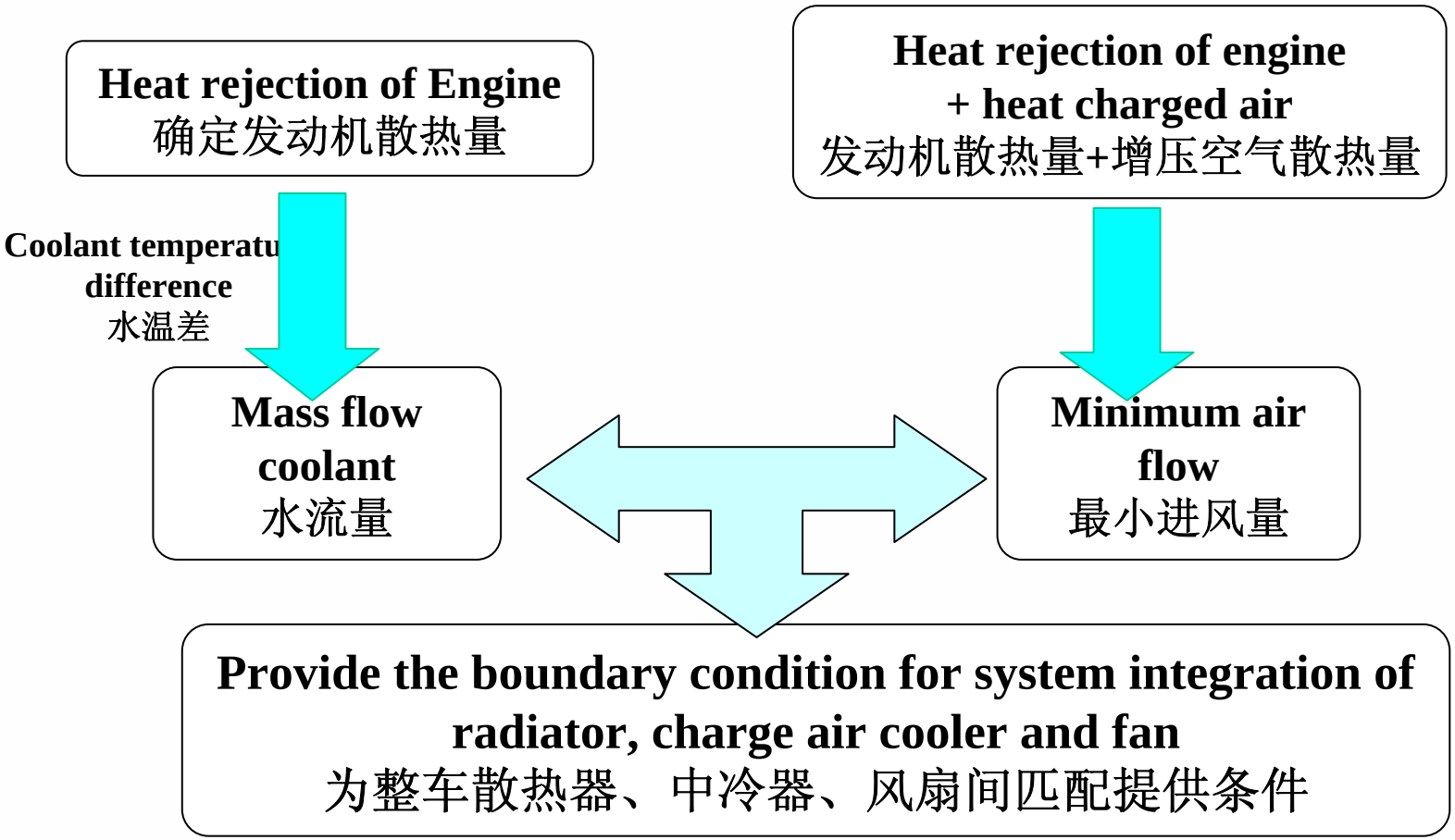
J5P EURO3 - Overheat / J5P欧3 冷却系统过热问题

Comparison between KULI simulation & road test
路试条件下的计算结果与道路试验数据对比

		KULI Simulation		Road Test	
		MaxP	MaxT	MaxP	MaxT
	Ambient Temp. (℃)	27.5	27.8	27.5	27.8
RAD	engine outlet Temp.	74.9	93.7	81.9	93.6
	engine inlet Temp.	71.0	88.1	77.4	87.8
	Temperature Diffenc	-3.8	-5.5	-4.5	-5.8
	Heat rejection (kw)	85.0	81.7		
	Volume flow (L/min)	327.1	219.5		
	Mass flow air side (kg/s	3.0	1.8		
	Mass flow density (kg/	5.2	3.1		
	Outlet Temp. OM (℃	72.2	91.8		
	Ambient ETD (℃)	47.4	65.9	54.4	65.8
	Permissible Temp. (	54.6	36.1	47.6	36.2
CAC	Inlet Temp. IM (℃)	172.6	162.1	174.4	168.6
	Outlet Temp. IM (℃	48.3	46.5	49.8	42
	Heat rejection (kw)	52.2	34.4		

Overheat @ MaxT
扭矩点处过热现象突出

II. System Analysis Workflow
系统分析方案流程



III. Heat rejection of the engine
发动机散热量输入

1：Experiment 试验对象

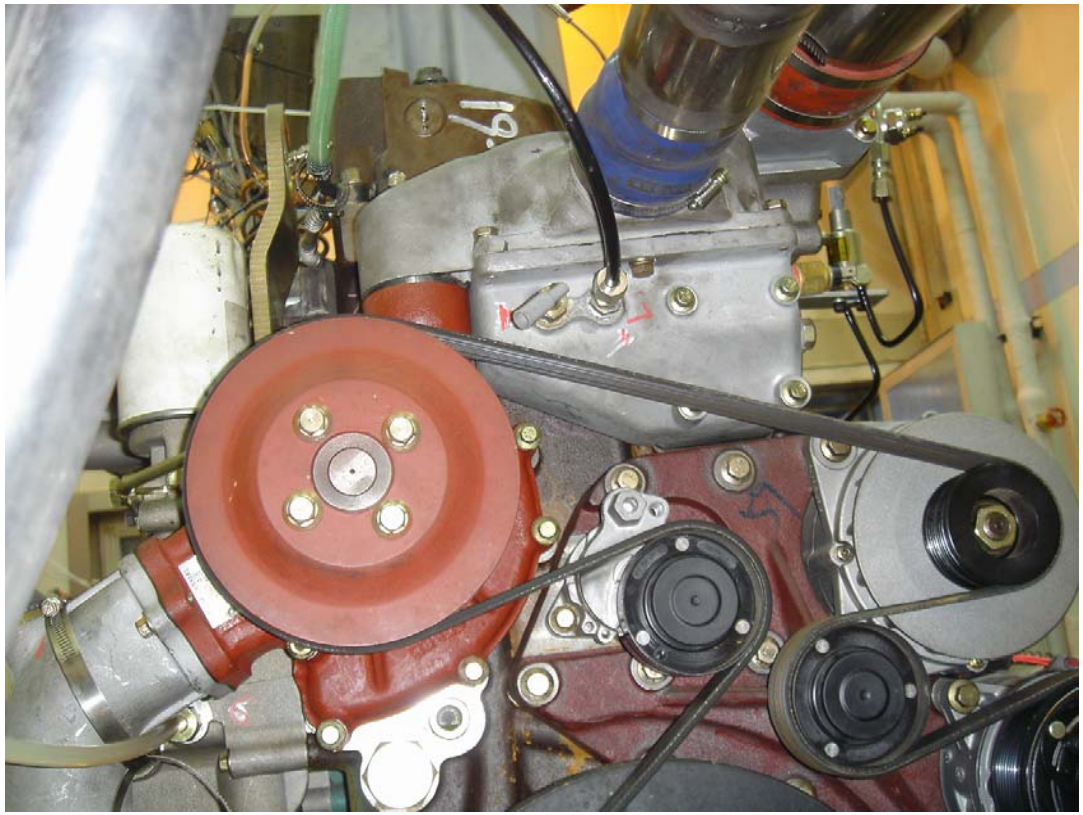
3 types of engine heat balance experiments:
共进行3种发动机台架热平衡试验，具体如下：

1#： Euro 2 engine: mechanical pump

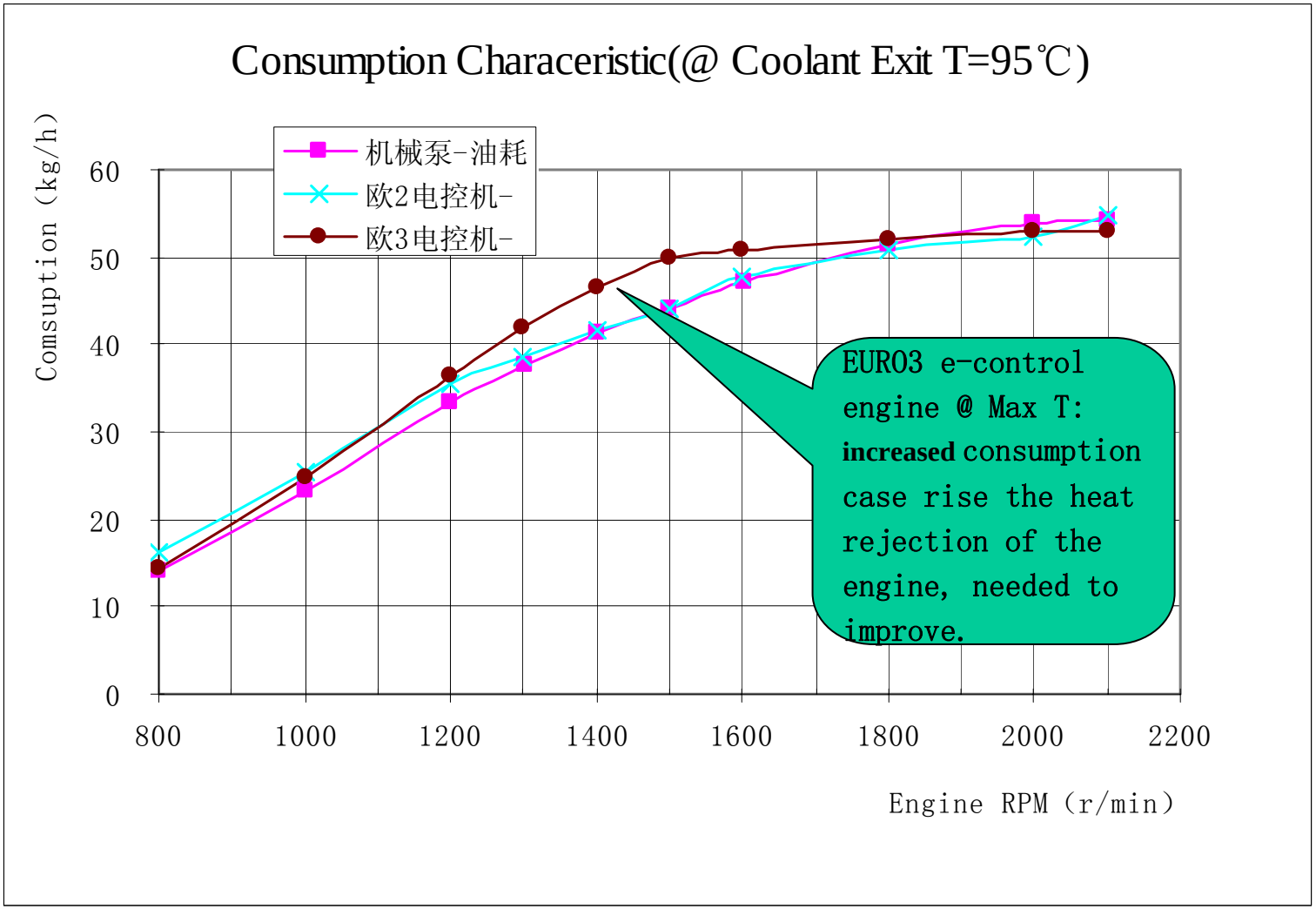
2#： Euro 2 engine: electrical control

3#： Euro 3 engine: electrical control

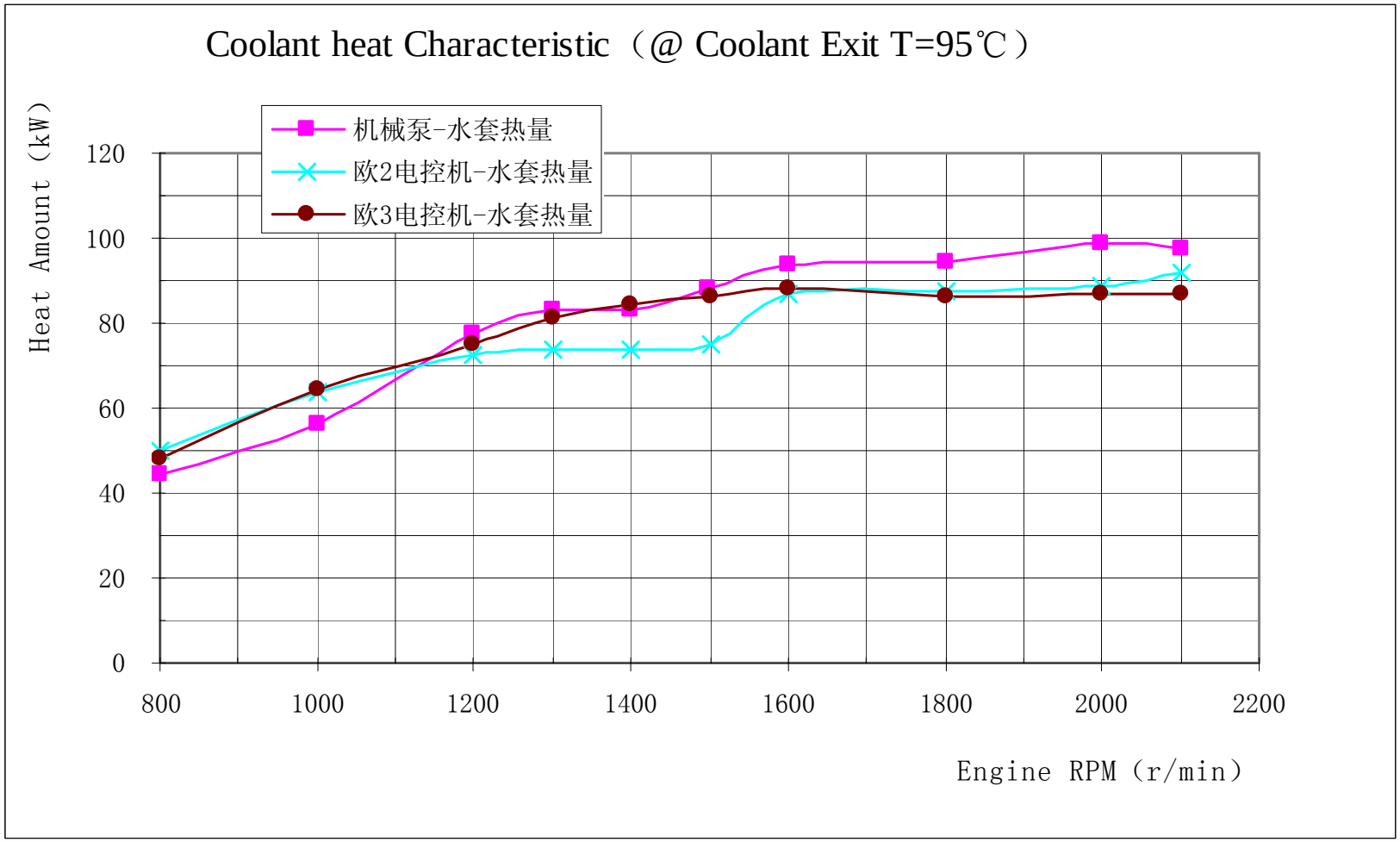
Benchmark test of the heat balance
发动机台架热平衡试验



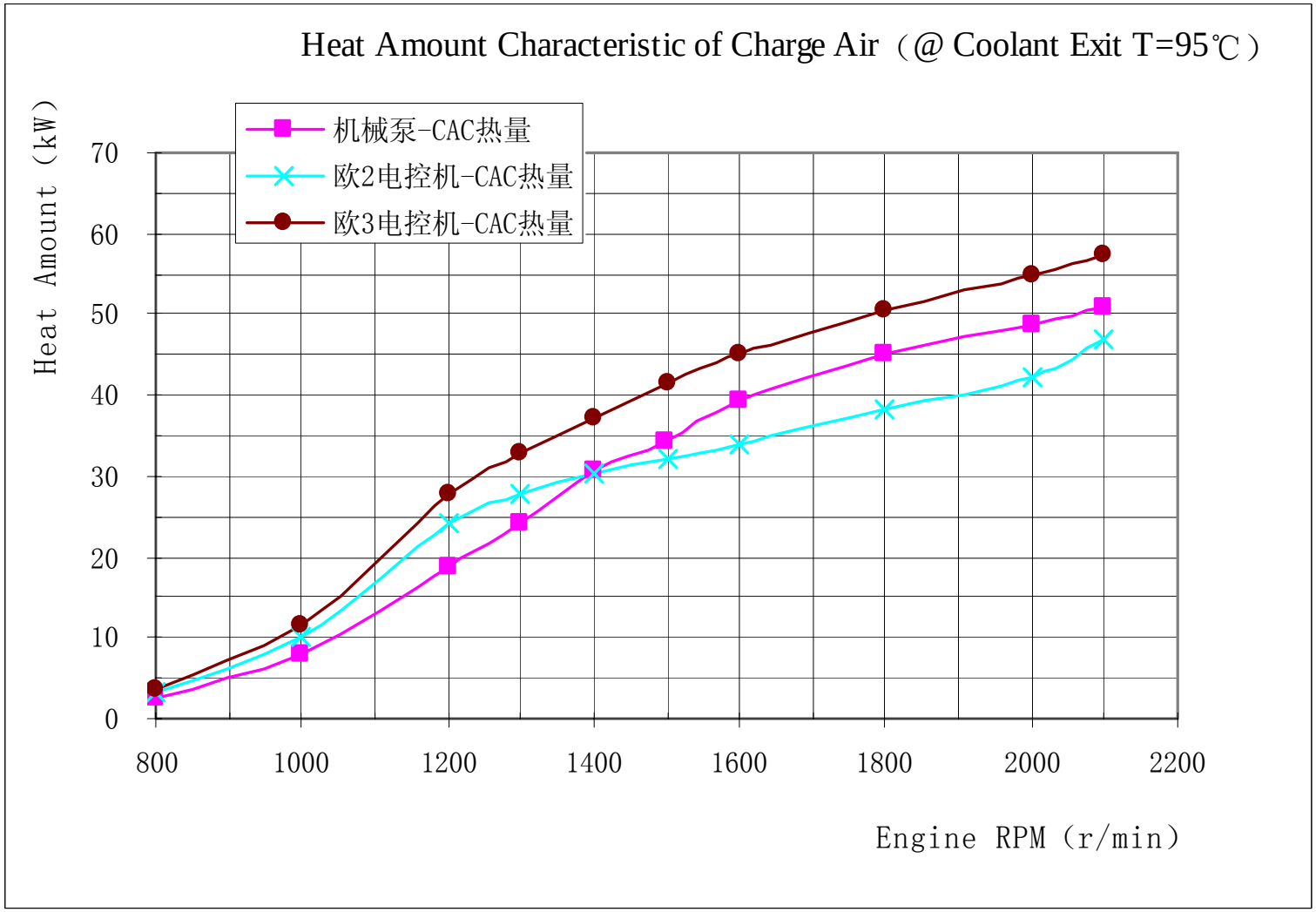
2、Engine Consumption Characteristic
发动机油耗对比曲线



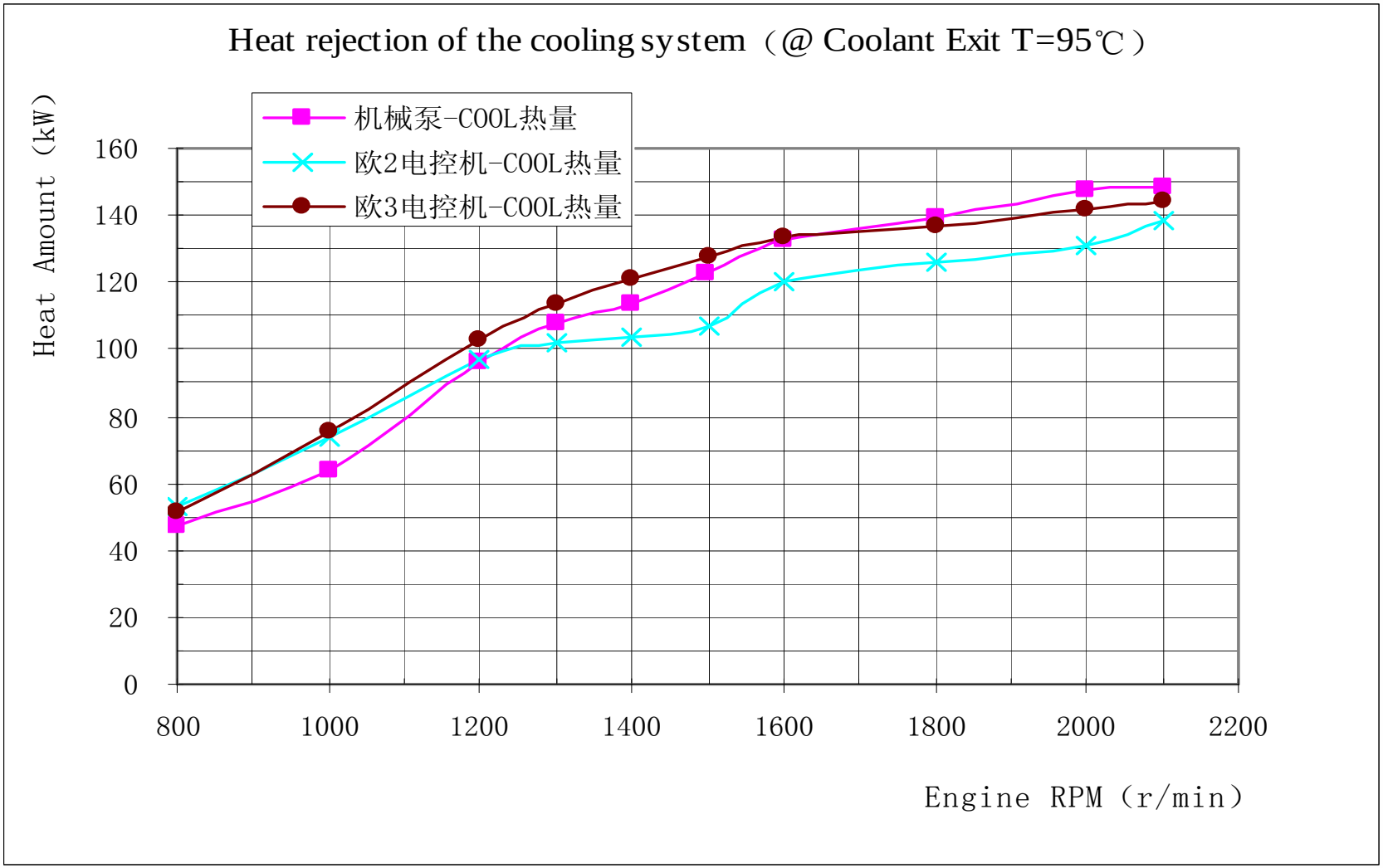
3）characteristic curve of the engine heat rejection Coolant Heat
3种发动机外特性散热量对比曲线 冷却水散热量



Charge air 增压空气散热量



Heat rejection of the cooling system
冷却系(冷却水+增压空气)散热量

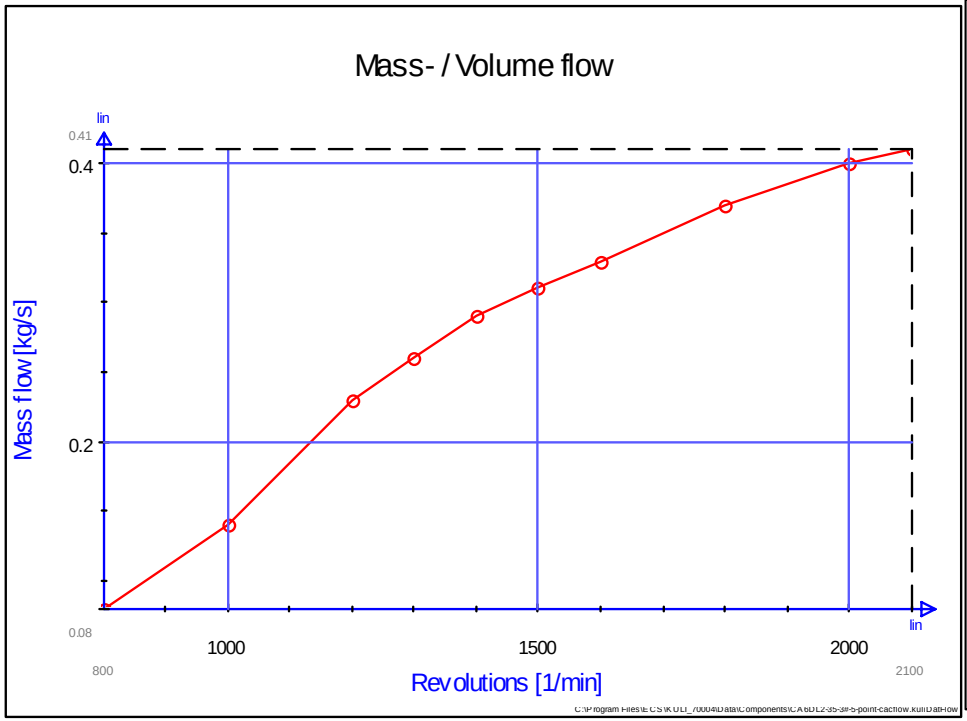


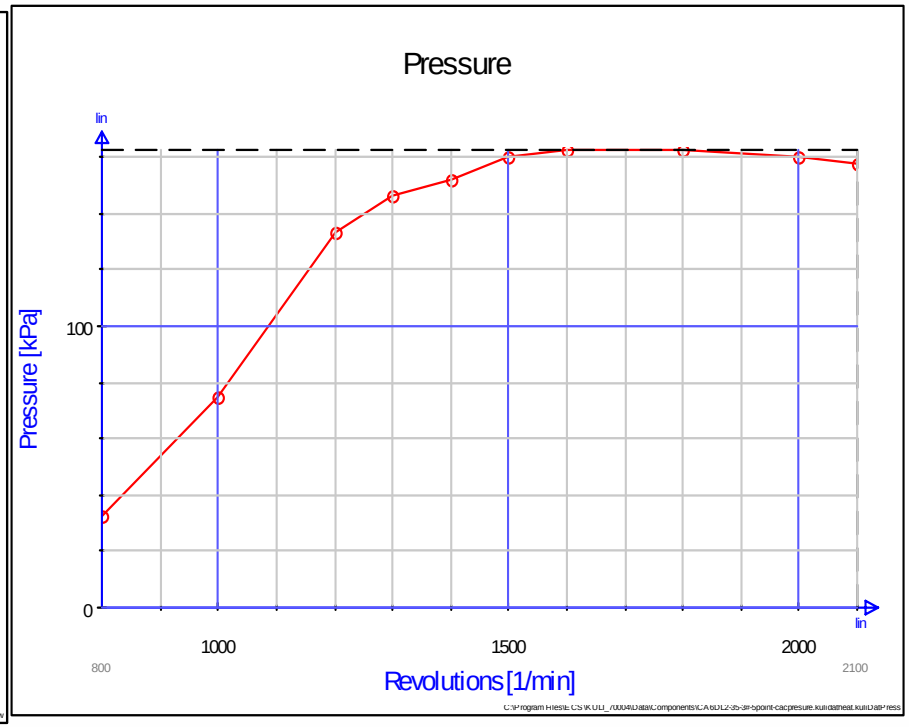
III. Engine model of the calculation 发动机计算模型

From the experiment, we know there is the overheat problem in J5p series especially in Euro 3 Emission engine. So, we select the 3# as the engine model in KULI.

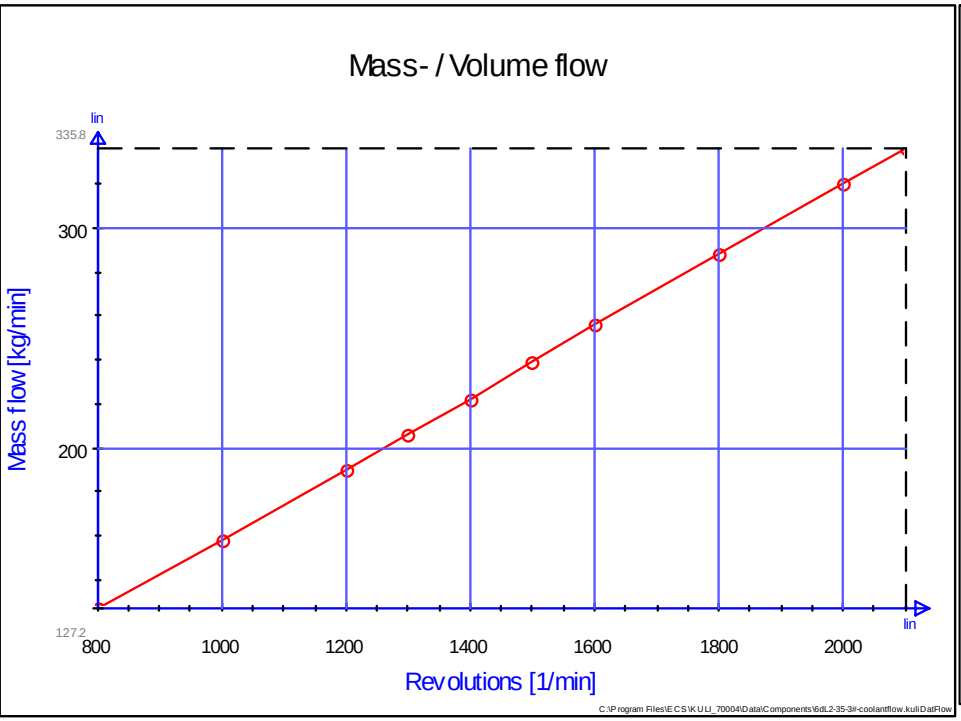
air flow of the charged air and pressure characteristic

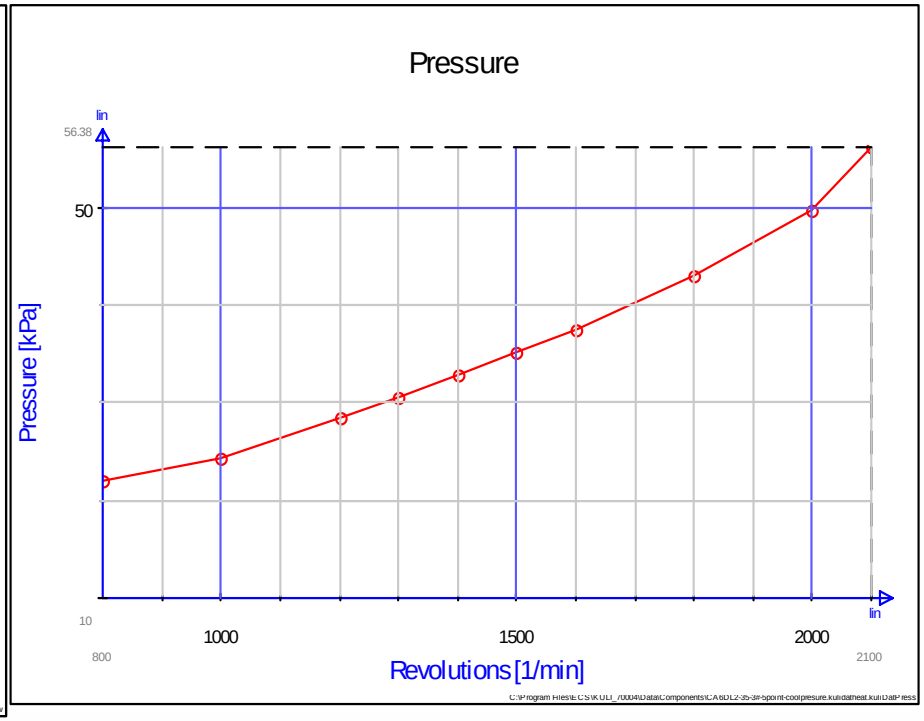
据整车试验反映，J5P冷却泵过热目前在欧3发动机车型中最突出，所以本次设计计算以3#发动机为主，增压空气流量和压力曲线如下：



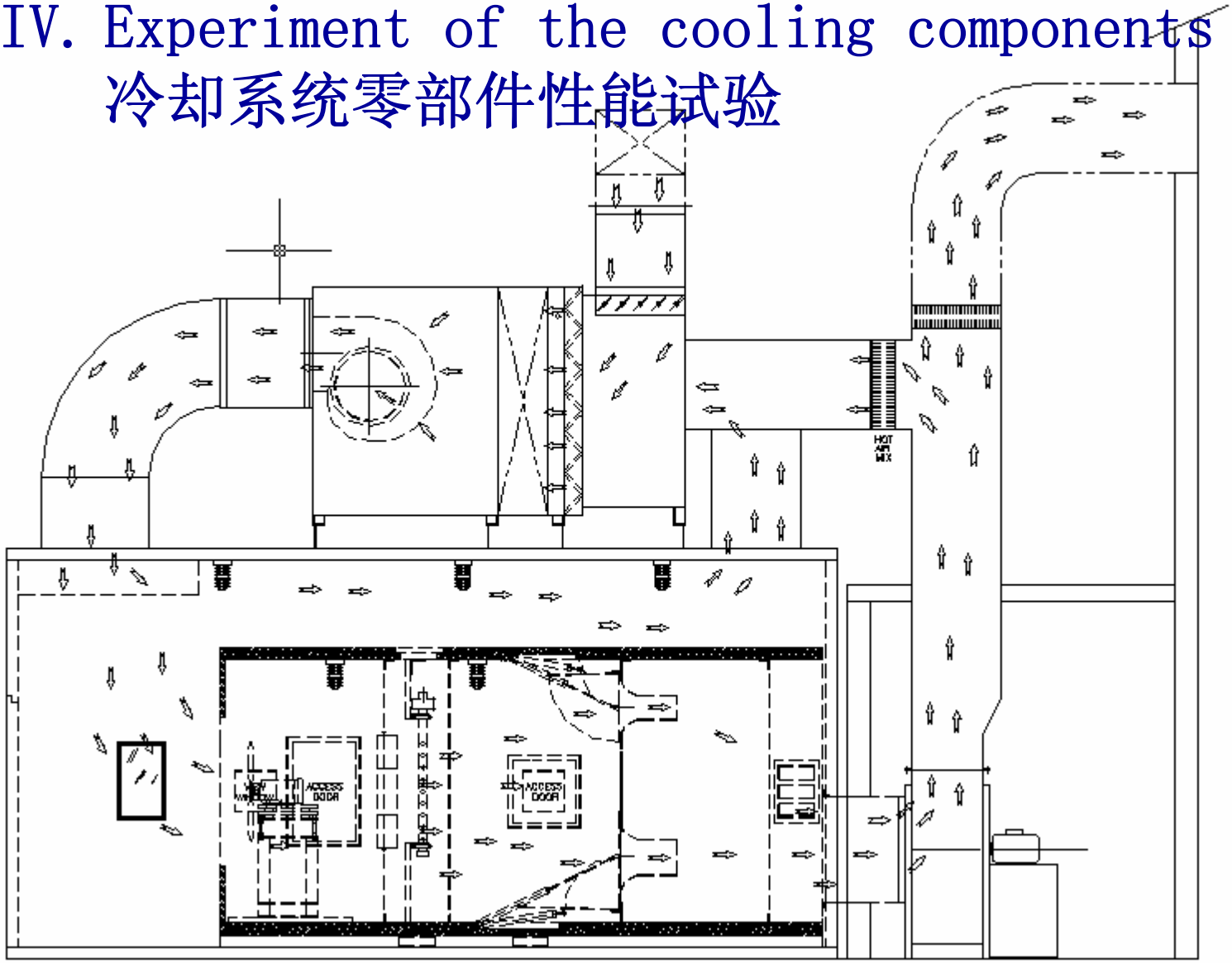


Coolant flow and Pressure characteristic as following:
发动机模型中，冷却水流量和曲线压力如下：





IV. Experiment of the cooling components
冷却系统零部件性能试验

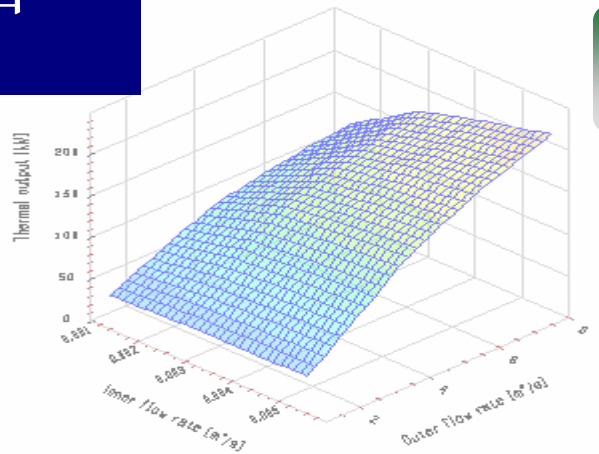


❑ Cooling Tests
冷却系统试验研究

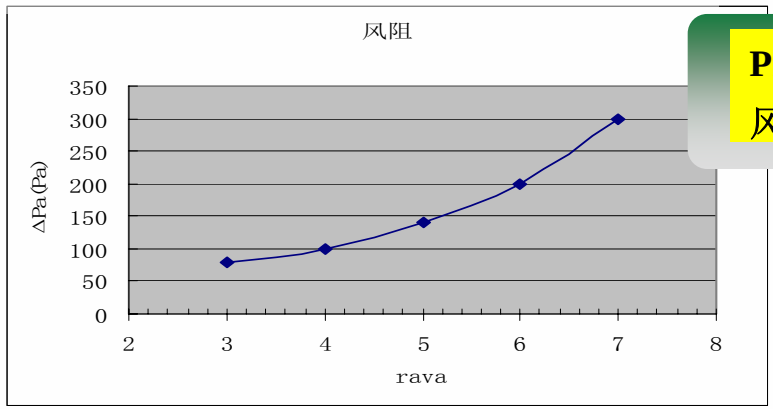
Equipments 设备基本信息

Items
试验项目

- Radiator 散热器性能
- Charge air cooler 中冷器性能
- Cooling package 模块性能

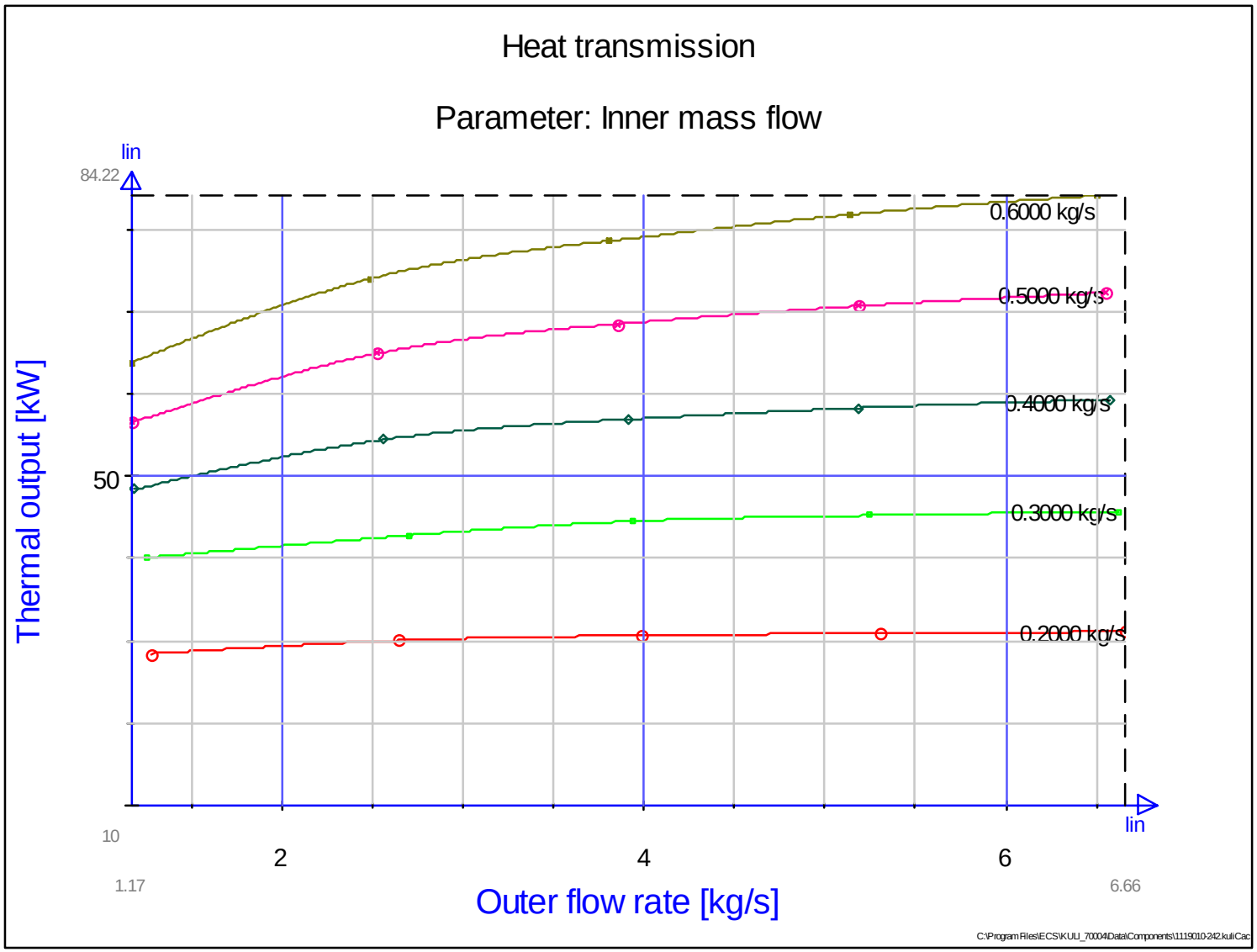


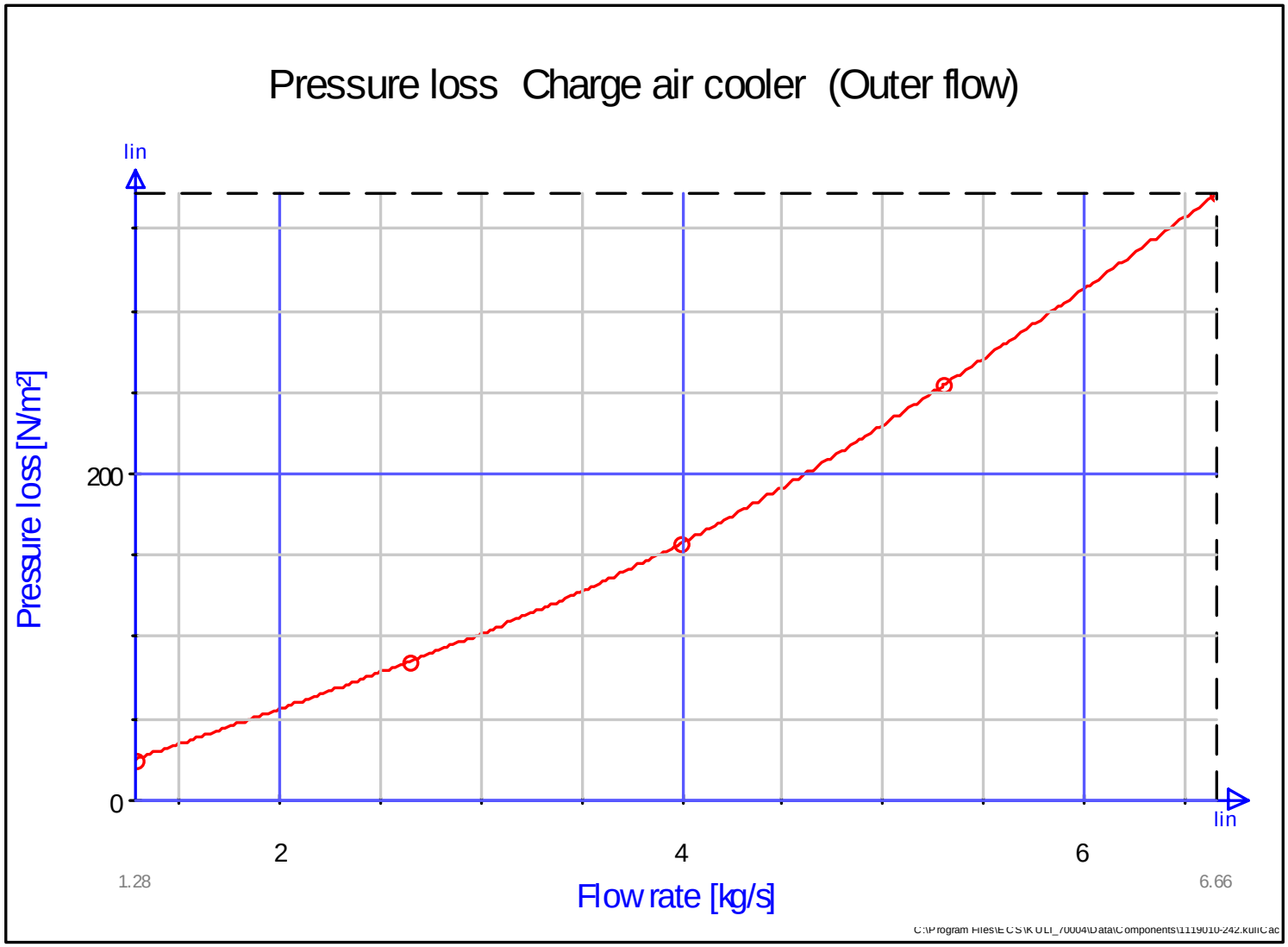
Cooling performance
散热性能



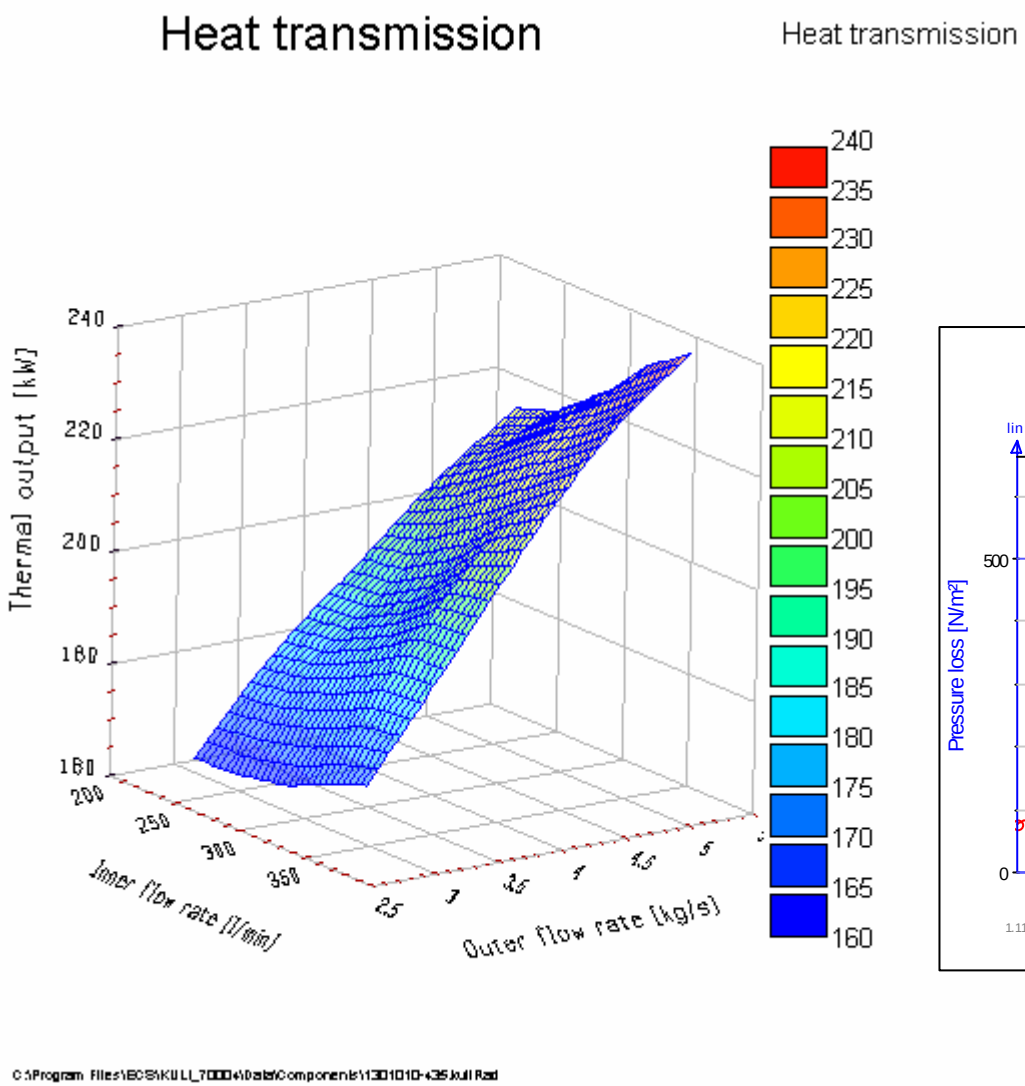
Pressure loss
风阻性能

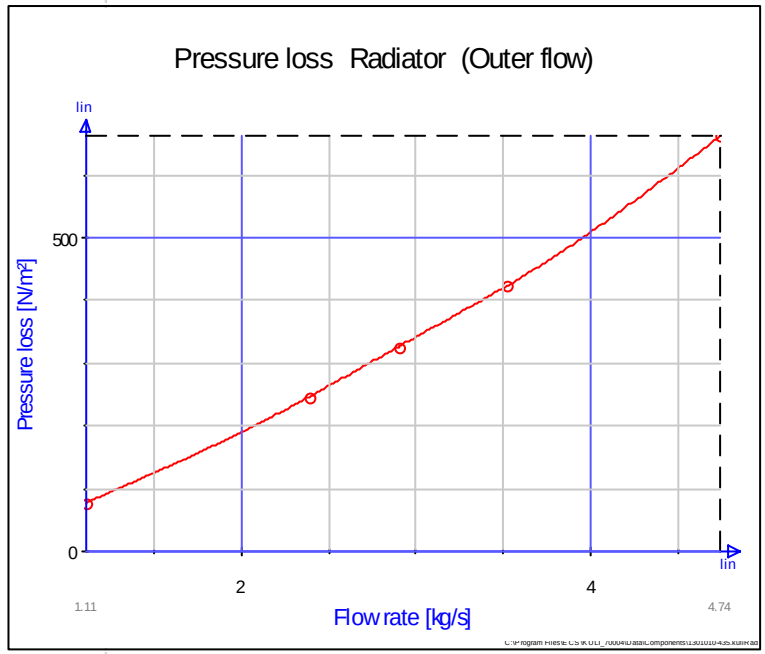
1）performance charge air cooler 中冷器性能



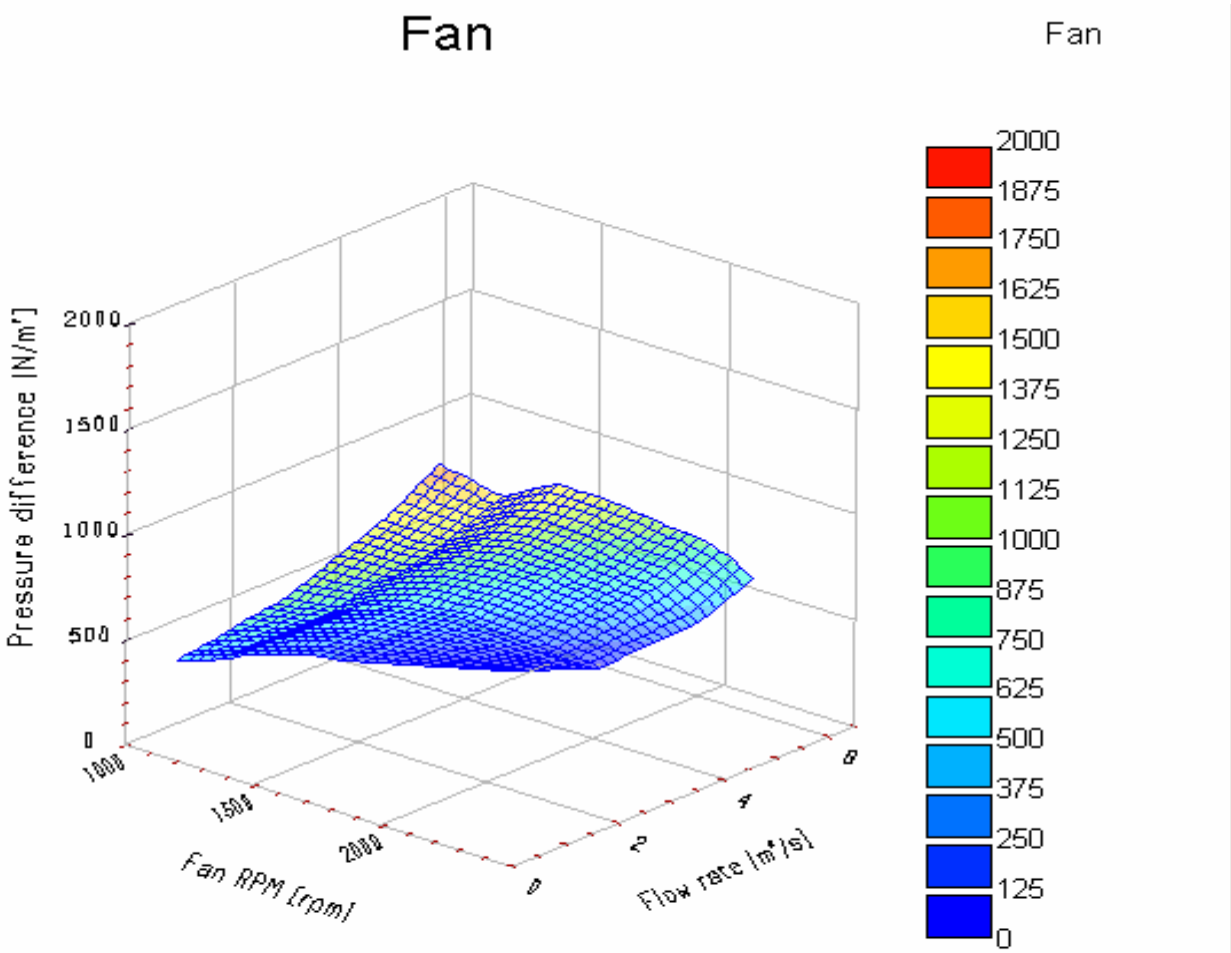

Pressure loss Charge air cooler (Outer flow)
lin
Pressure loss [N/m²]
200
0
lin
2
4
6
1.28
6.66
Flow rate [kg/s]

2）Performance Radiator 散热器性能





3）Performance fan 风扇性能

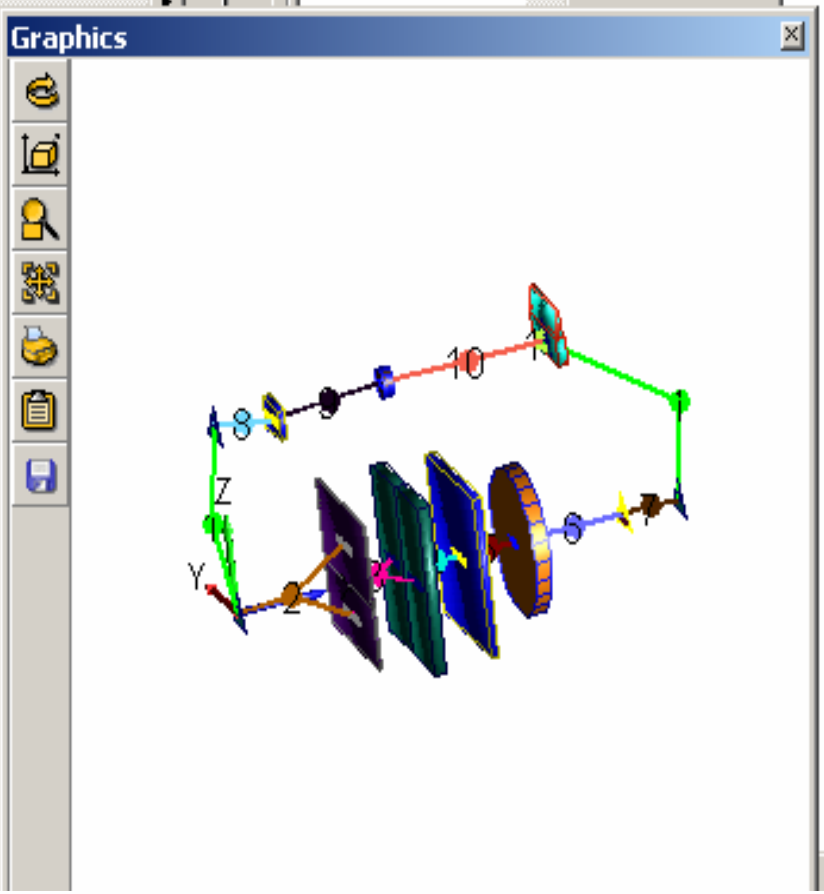


V. System model of the cooling system 整车稳态计算模型如下

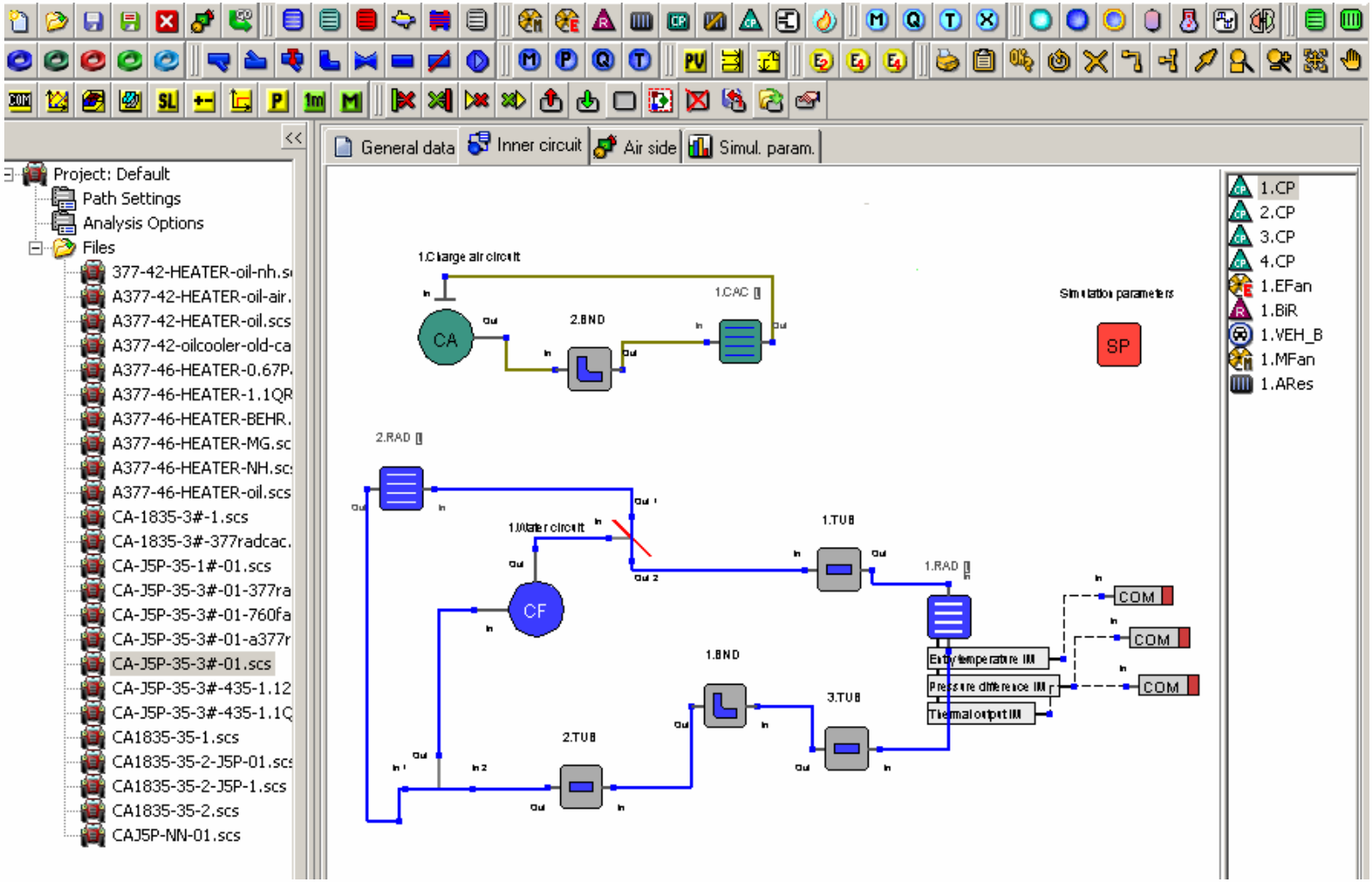
air path of the cooling system 冷却系统空气侧

Nodes Use only 1. element

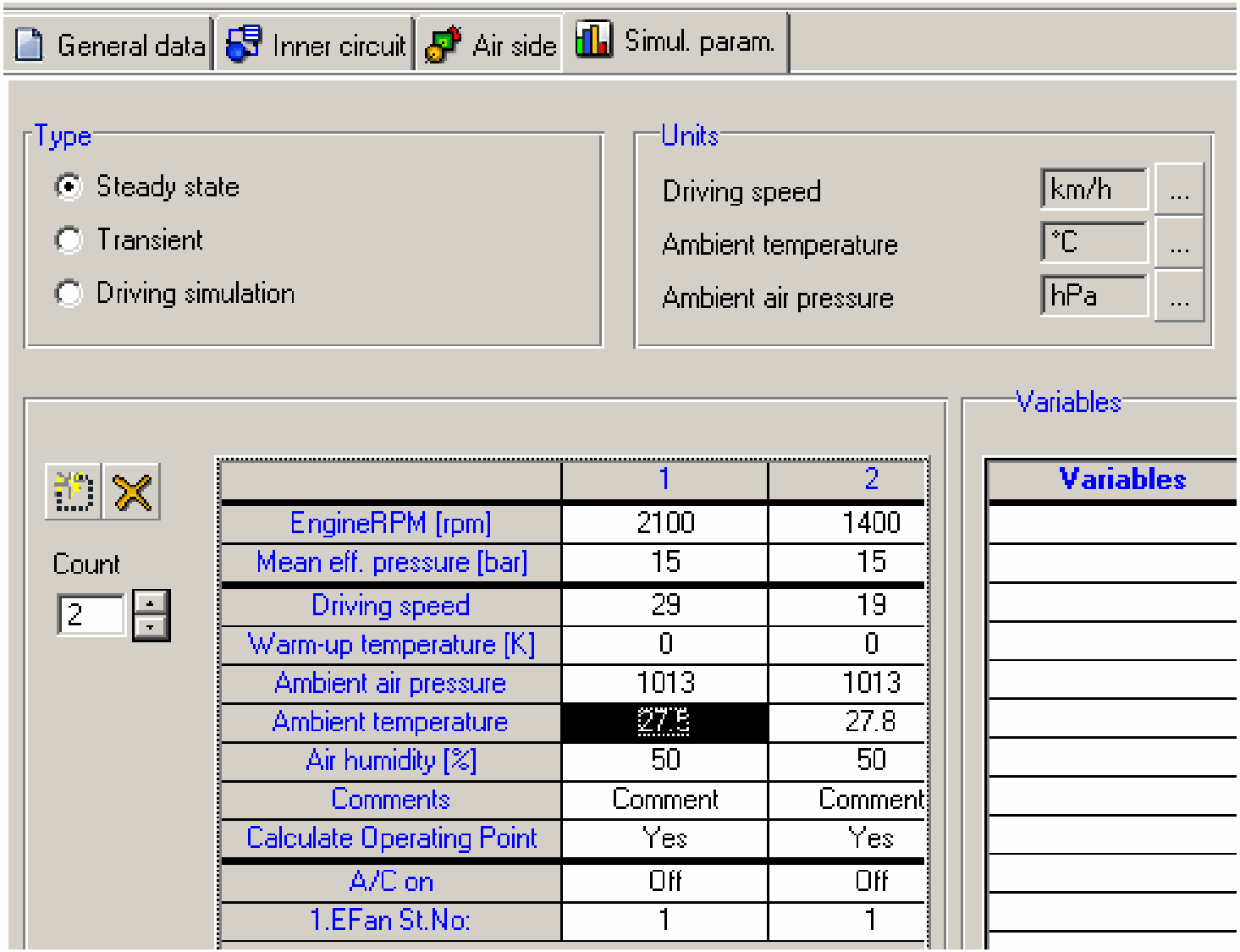
Nodes	Previous	Next
1	2.CP;1.VEH_B	1.CP;3.CP
2	1.CP	1.ARes[1,1];1.ARes[1,2]
3	1.ARes[1,1];1.ARes[1,2]	1.CAC[1,1];1.CAC[2,1]
4	1.CAC[1,1];1.CAC[2,1]	1.RAD[1,1]
5	1.RAD[1,1]	1.MFan
6	1.MFan	1.BiR
7	1.BiR	2.CP
8	3.CP	2.RAD[1,1]
9	2.RAD[1,1]	1.EFan
10	1.EFan	4.CP
11	4.CP	1.VEH_B



Stationary operation point of the cooling system（inner circuit）整车稳态计算模型（液侧）



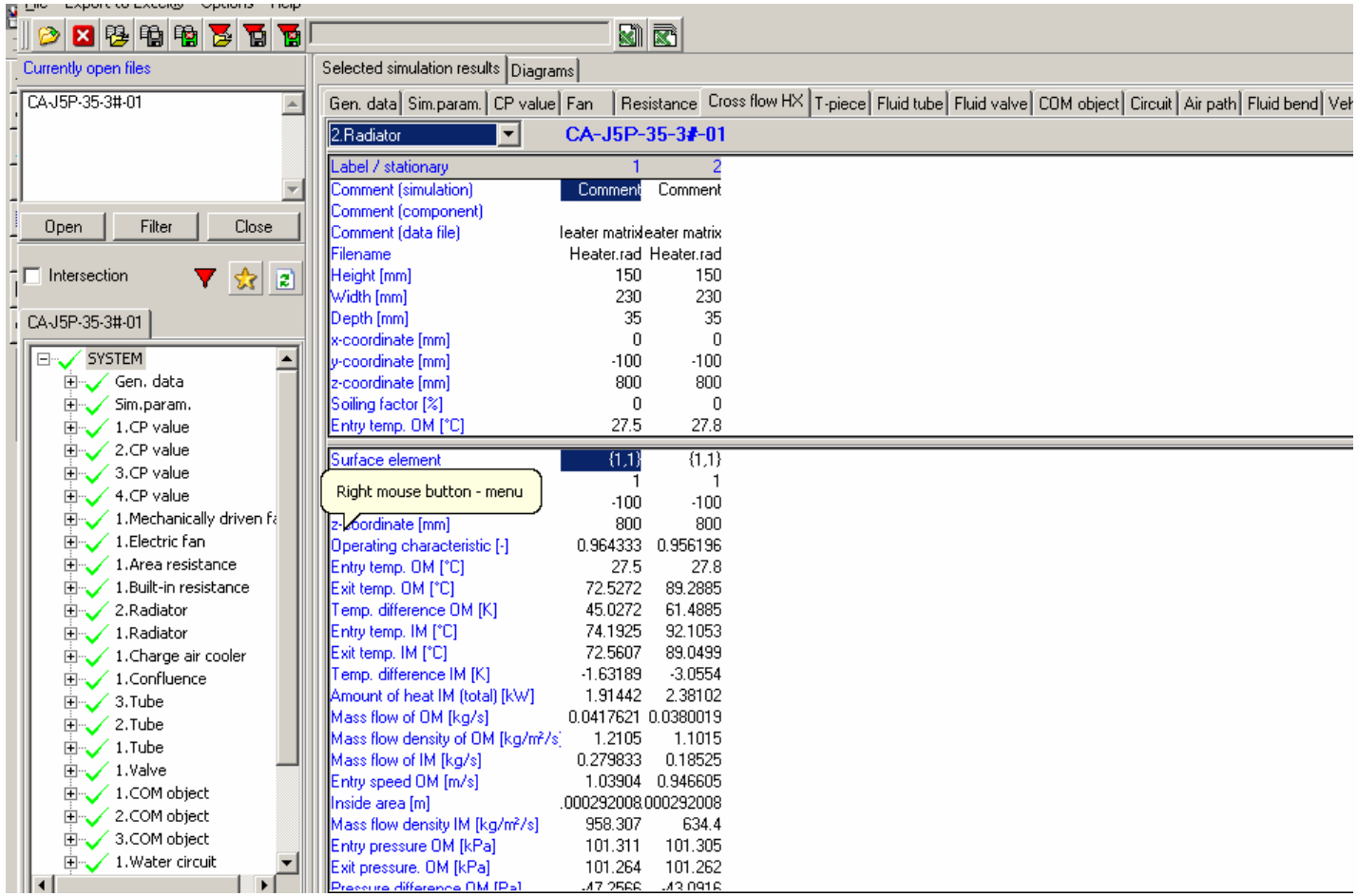
Operation point: (Max P & Load) 计算工况点 （功率点、扭矩点）



	1	2
EngineRPM [rpm]	2100	1400
Mean eff. pressure [bar]	15	15
Driving speed	29	19
Warm-up temperature [K]	0	0
Ambient air pressure	1013	1013
Ambient temperature	27.5	27.8
Air humidity [%]	50	50
Comments	Comment	Comment
Calculate Operating Point	Yes	Yes
A/C on	Off	Off
1.EFan St.No:	1	1

VI. KULI result & Post processor 计算结果和后处理分析

KULI can be used to simulation of the system integration, we can calculate the operation point of the components and we can review and analyze the results in the Postprocessor.
软件可对模型系统进行匹配和计算，算出各节点的状态参数，并可对各点进行后处理和分析，见下图。



Improvement solution 2 & 7 （Top High T=102℃）
改进方案对比分析 （最高水温102℃计算）

	original	2# solution	7# solution
Ambient Temp. （℃）	27.8	27.8	27.8
Engine Exit Temp. （℃）	93.7	91.5	87.4
Engine entry Temp.(℃)	88.1	86.0	81.8
Temperature Diff. （℃）	-5.5	-5.5	-5.5
Coolant heat （kw）	81.7	81.8	81.9
Coolant flow （l/min）	219.5	219.1	218.5
Air flow （kg/s)	1.8	1.9	2.0
Air flow density （kg/m2s)	3.1	2.8	3.5
Air Exit Temp. （℃）	91.8	88.9	85.3
Ambient ETD（℃）	65.9	63.7	59.6
Permissible Temp. （℃）	36.1	38.3	42.4
CAC Entry Temp. （℃）	162.1	162.1	162.1
CAC Exit Temp （℃）	46.5	45.8	45.6
Heat charged air (kw)	34.4	34.6	34.6
mass flow （kg/s）	0.3	0.3	0.3
Original			
2# solution	big rad&cac		
7# solution	740 fan		

J5P 350Ps EURO3 - Overheat

J5P overheat & improvement design 过热问题分析和改进设计

- From KULI simulation, we found it wouldn't fulfill the heat request, if improve the radiator and charge air cooler only @ Max T.

根据KULI模拟计算方案对比分析，发现只改进散热器和中冷器，不能满足扭矩点散热要求，无法满足系统设计目标。

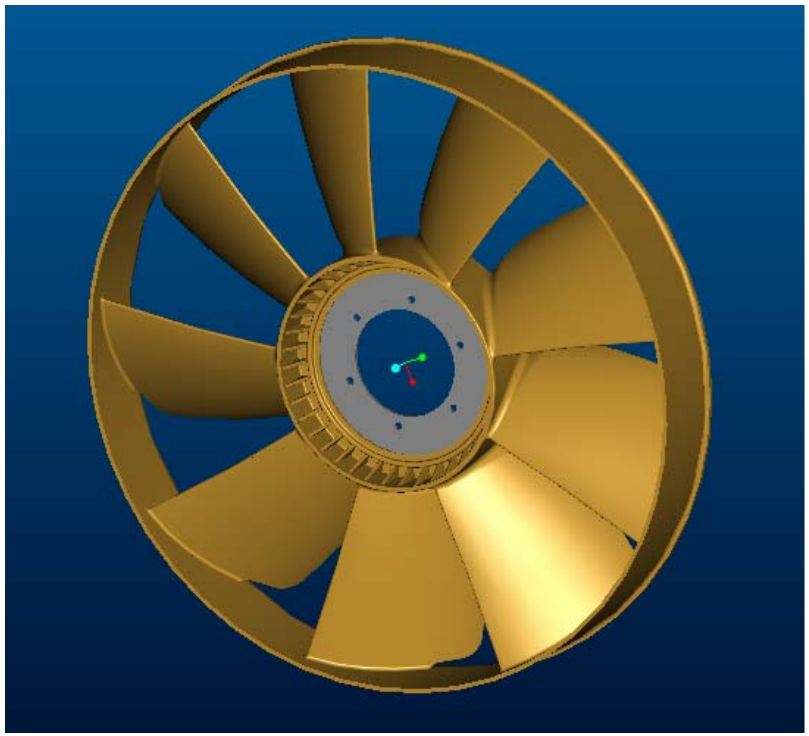
- For the original designing, at operation point of Max T, the mass flow of the air was too little, that mainly cause the problem of the overheat. So we need to improve the air flow of the cooling system. We need a new fan to improve the mass flow by 15% higher.

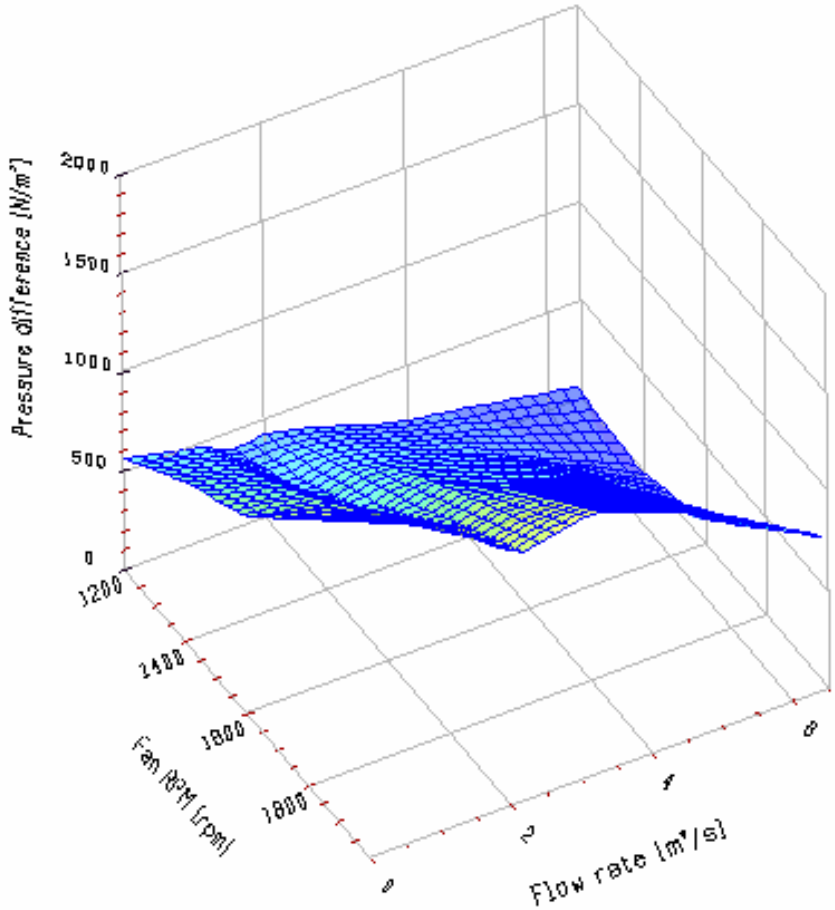
原车扭矩点的风量小，是J5P过热的主要原因，因此必须在提高风量方面进行改进。设计新风扇，要求风扇风量提高15%以上。

J5P EURO3 - Overheat

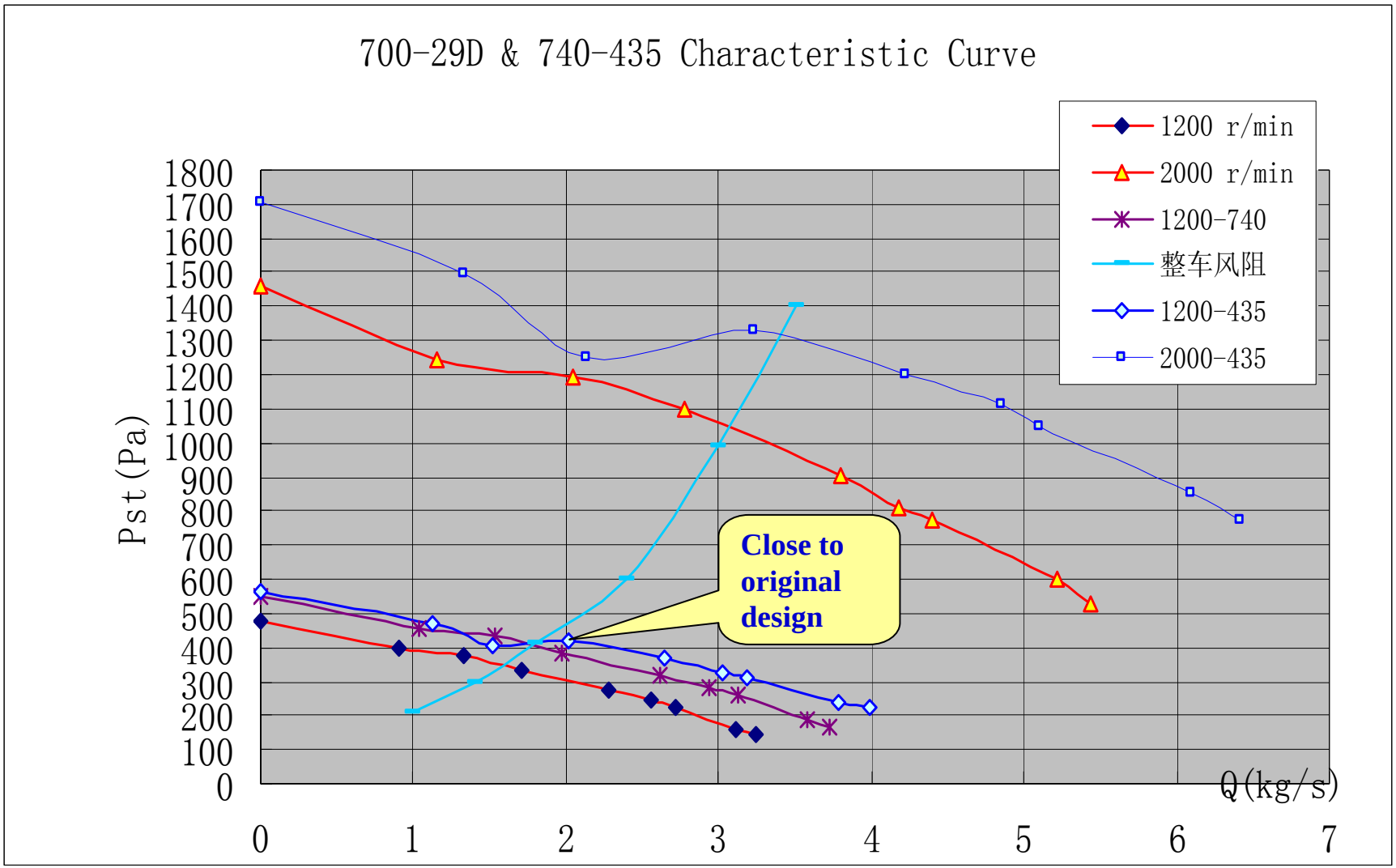
J5P Improvement 改进设计:

J5P Euro3 New Fan 新风扇试制





J5P EURO3 - Overheat



J5P EURO3 - Overheat

Results comparison with the new fan & Road Test（@Load）
新风扇条件下整车计算结果与道路试验数据对比（扭矩点工况）

		Simulation			Road Test	
		Original	1S	2S-New Fan	Original	2S-New Fan
	Ambient Temp. (℃)	27.8	27.8	27.8	27.8	30.5
RAD	Engine Exit Temp. (	93.7	87.4	86.2	93.6	89.6
	Engine Engry Temp.	88.1	81.8	80.7	87.8	83.5
	Temperature Diff. (	-5.5	-5.5	-5.5	-5.8	-6.1
	Coolant Heat（kw）	81.7	81.9	82.0		
	Coolant Flow（L/min）	219.5	218.5	218.3		
	Air Mass Flow（kg/s)	1.8	2.0	2.0		
	Air flow density（kg/m^2	3.1	3.5	3.5		
	Air exit Temp. (℃)	91.8	85.3	84.0		
	Ambient ETD (℃)	65.9	59.6	58.4	65.8	59.1
	Permissible Temp. (	**36.1**	**42.4**	**43.6**	**36.2**	42.9
CAC	Entry Temp. (℃)	162.1	162.1	162.1	168.6	
	Exit Temp. (℃)	46.5	45.6	45.4	42	
	Heat Amount kw)	34.4	34.60	34.7		

Fulfill the request, experiment needed

Road test
道路试验

Combination with KULI simulation and experiment, we success improve the cooling system of the truck!

经过设计计算和试验结合，该车的冷却系统改进获得成功！

Thanks for your attention!