优化理论与最优控制

Prof . Dr . -ing L. Wang

什么是优化（第一个例子：文献）

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Optimization of wind turbine energy and power factor with an evolutionary computation algorithm

Andrew Kusiak*, Haiyang Zheng

Department of Mechanical and Industrial Engineering, 3131 Seamans Center, The University of Iowa, Iowa City, IA 52242-1527, USA

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ABSTRACT

An evolutionary computation approach for optimization of power factor and power output of wind turbines is discussed. Data-mining algorithms capture the relationships among the power output, power factor, and controllable and non-controllable variables of a 1.5 MW wind turbine. An evolutionary strategy algorithm solves the data-derived optimization model and determines optimal control settings. Computational experience has demonstrated opportunities to improve the power factor and the power output by optimizing set points of blade pitch angle and generator torque. It is shown that the pitch angle and the generator torque can be controlled to maximize the energy capture from the wind and enhance the quality of the power produced by the wind turbine with a DFIG generator. These improvements are in the presence of reactive power remedies used in modern wind turbines. The concepts proposed in this paper are illustrated with the data collected at an industrial wind farm.

An evolutionary computation approach for optimization of power factor and power output of wind turbines is discussed Data-mining algorithms capture the relationships among the power output, power factor, and controllable and non-controllable variables of a 1.5 MW wind turbine An evolutionary strategy algorithm solves the data-derived optimization model and determines optimal control settings Computational experience has demonstrated opportunities to improve the power factor and the power output by optimizing set points of blade pitch angle and generator torque It is shown that the pitch angle and the generator torque can be controlled to maximize the energy capture from the wind and enhance the quality of the power produced by the wind turbine with a DFIG generator These improvements are in the presence of reactive power remedies used in modern wind turbines The concepts proposed in this paper are illustrated with the data collected at an industrial wind farm

书签

- Optimization of wind turbine energy and power factor with an evolutionary computation algorithm
  - Introduction
  - Problem formulation and methodology
    - Power optimization problem formulation
    - Dynamic modeling of wind turbines
    - The bi-objective power optimization model
  - Wind turbine modeling
    - Data description
    - Dynamic models extracted by the data-mining algorithms
  - Bi-objective power optimization
    - Low wind speed scenario
    - High wind speed scenario
  - Conclusion
  - Acknowledgement
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什么是优化（第二个例子：水网络）

来源于工业的例子

工业需求

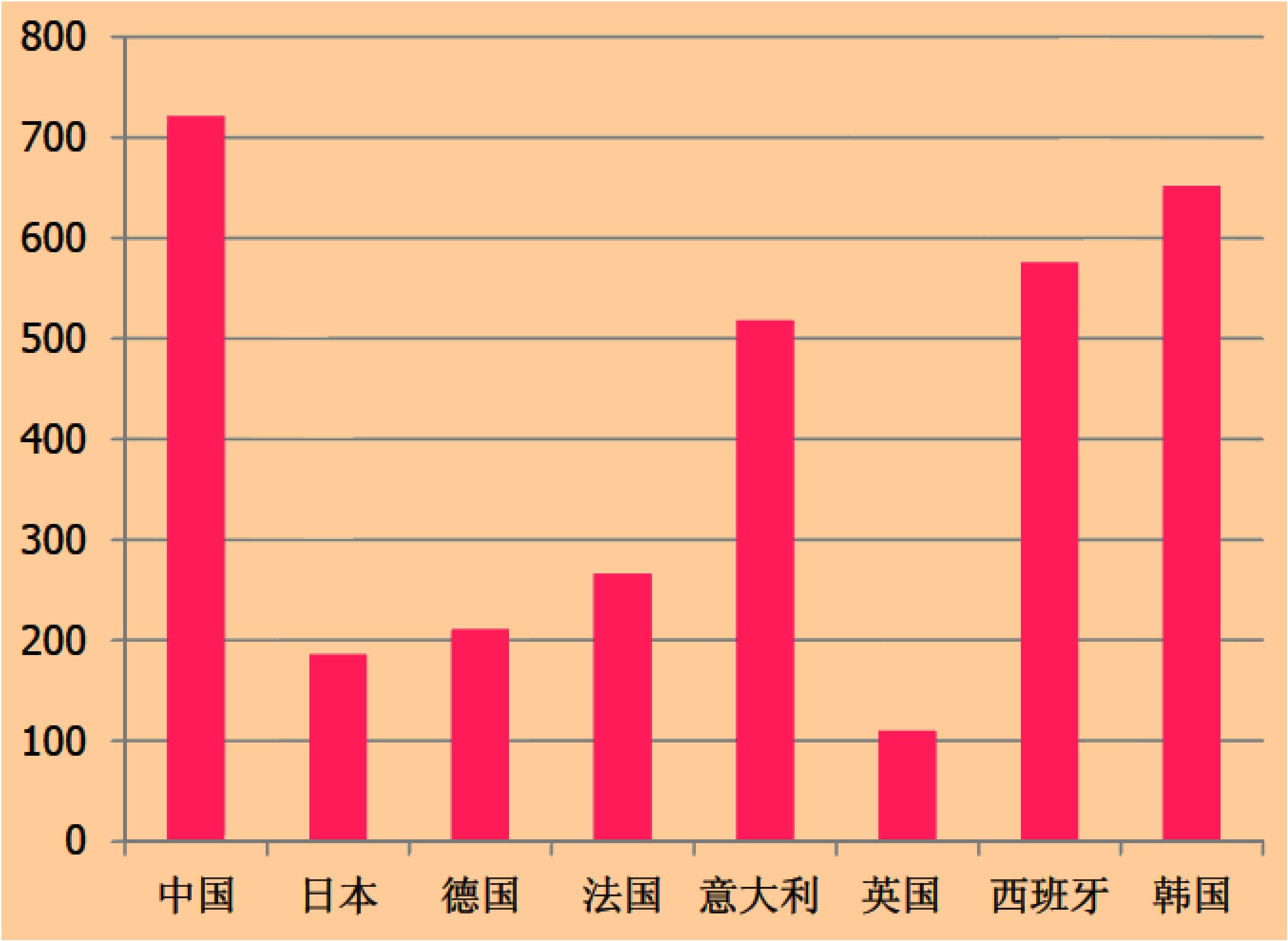
思考需求

生存需求

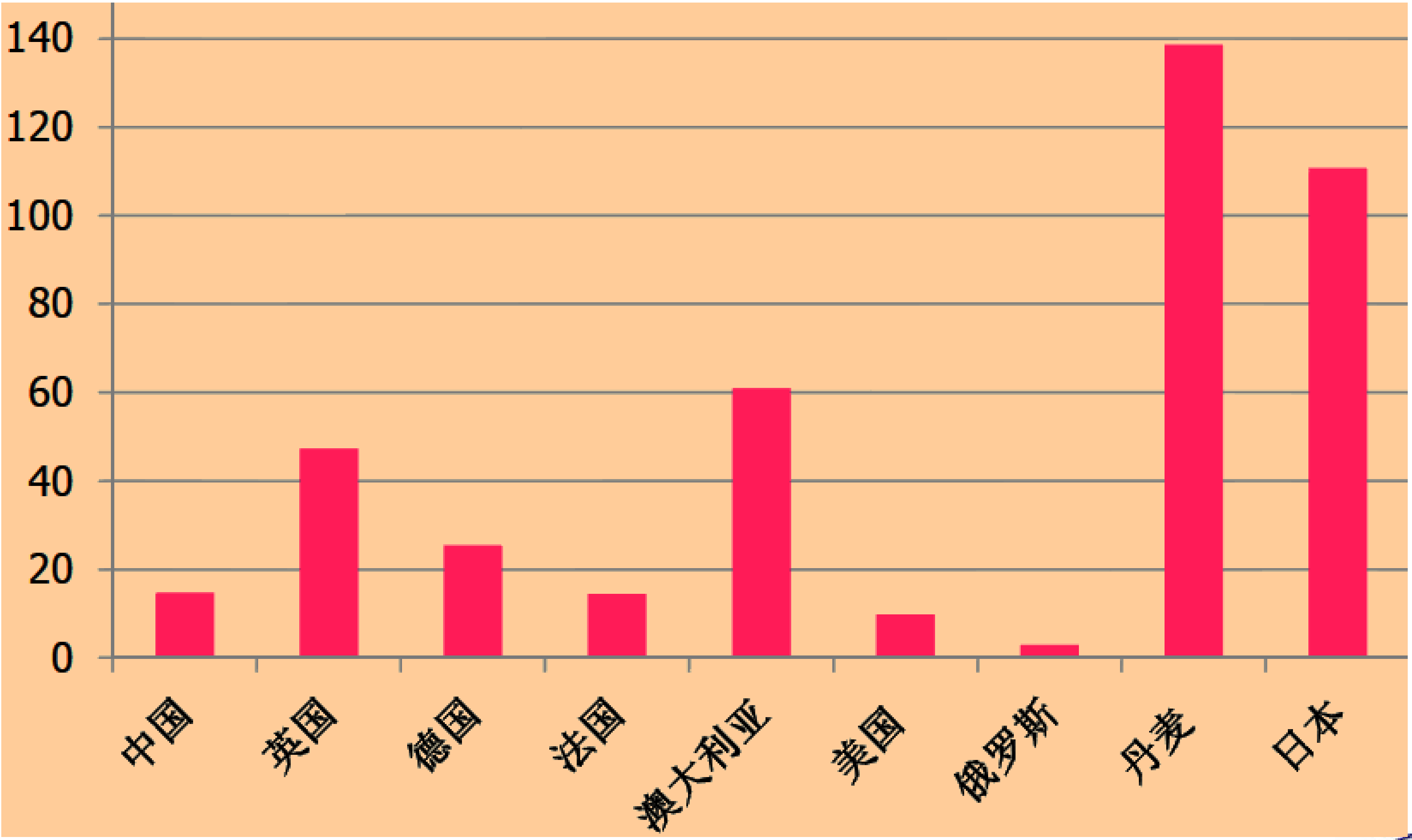
I. 水危机是全球性的，中国尤其严重

1. 地球上所有的水中，只有2.5%是淡水。
2. 20世纪世界人口增加近三倍，淡水消耗量增加了6倍，其中工业用水增加了26倍，但水资源并未增加。20世纪末人均占有水量仅为世纪初的1/18。地球上的可饮用水正在面临枯竭。
3. 全世界每年排放工业废水$4260*10^8 m^3$,这使得可供人类使用的1/3淡水资源受到污染。
4. 12亿人口会由于缺乏净水而陷入困境。
5. 26亿人口缺乏充分的卫生设施条件保障。

II. 单位GDP用水量(m^3/万美元)



III. 工业用水效率(万美元/m³)



IV. 对策（政策层面）

确立水资源开发利用控制的三条红线:

到2030年全国用水总量控制在7000亿立方米以内；

万元工业增加值用水量降低到40立方米以下；

2020年，全国用水总量力争控制在6700亿立方米以内；

万元工业增加值用水量降低到65立方米以下；

2015年，全国用水总量力争控制在6350亿立方米以内；

万元工业增加值用水量比2010年下降30%以上

2010年实际万元工业增加值用水量为105立方米。

2015年控制值是： 73.5立方米

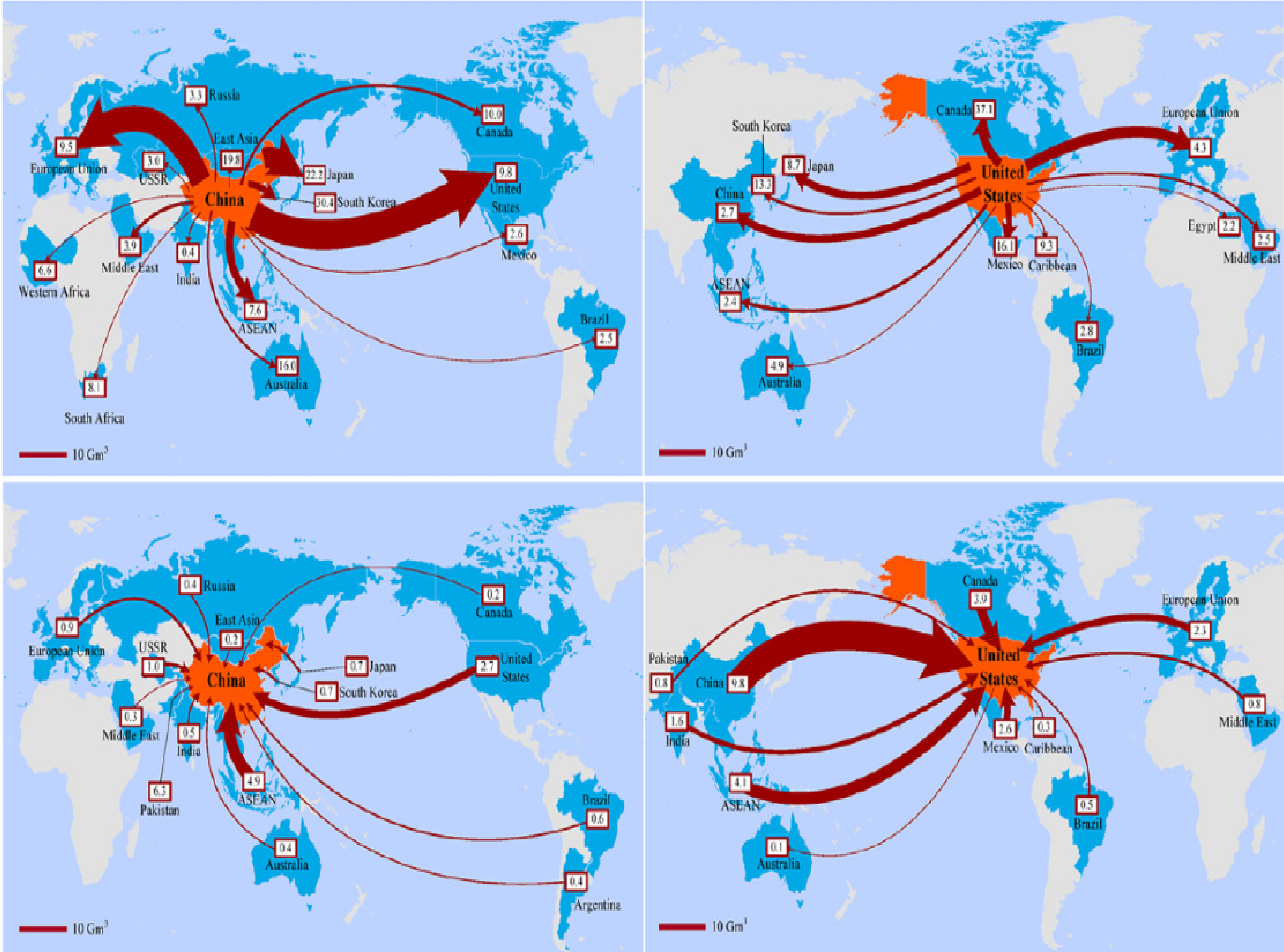
IV. 对策（技术层面—经济学）

联合国教科文组织的研究表明：

中国因为没有在国际贸易中考虑虚拟水问题，

在1996—2005年的贸易中已导致虚拟水净损失

235亿立方米。



3.3 Russia
10.0 Canada
9.5 European Union
East Asia 19.8
3.0 USSR
22.2 Japan
China
30.4 South Korea
9.8 United States
6.6 Western Africa
3.9 Middle East
0.4 India
2.6 Mexico
7.6 ASEAN
Brazil 2.5
16.0 Australia
8.1 South Africa
10 Gm^3
Canada 37.1
European Union 4.3
South Korea 13.3
8.7 Japan
United States
China 2.7
Egypt 2.2
2.5 Middle East
16.1 Mexico
9.3 Caribbean
ASEAN 2.4
2.8 Brazil
4.9 Australia
10 Gm^3
0.4 Russia
0.2 Canada
0.9 European Union
East Asia 0.2
USSR 1.0
China
0.7 Japan
0.7 South Korea
2.7 United States
0.3 Middle East
0.5 India
6.3 Pakistan
4.9 ASEAN
Brazil 0.6
0.4 Australia
0.4 Argentina
10 Gm^3
Canada 3.9
European Union 2.3
Pakistan 0.8
China 9.8
United States
1.6 India
0.8 Middle East
2.6 Mexico
0.3 Caribbean
4.1 ASEAN
0.5 Brazil
0.1 Australia
10 Gm^3

IV. 对策（技术层面－工学）

1. 工业企业内水网络系统集成优化

   A. 单个水网络系统

   B. 同时优化水用量最小和能量最小（生产力最大）

   C. 多原料(如煤、天然气等)工艺与能水系统同时优化

2. 跨企业多个水网络系统集成优化（工业园区）

3. 城市水网络问题

IV. 对策（技术层面－工学）

<u>优化的目标函数问题</u>：

1. 新鲜水用量最小化：

以此为目标函数有片面性– 可能导致“花钱买指标”；

2. 水系统运行总成本最小化：

水系统涵盖范围大了后，成本就显著上升了；

IV. 对策（技术层面—工学）

优化变量：结构中的联接数目N_S

1. 新鲜水用量最小化：

目标： min $$\sum_{j=1}^{N_s} F_j$$

约束： s.t.

$$W_i = \sum_{j=1}^{N_S} w_{i,j} + w_{i,\mathrm{waste}} \,(j = 1, 2, \cdots, N_s)$$

$$G_j = F_j + \sum_{i=1}^{N_R} w_{i,j} \,(j = 1, 2, \cdots, N_s)$$

$$G_j z_j^{in} = \sum_{i=1}^{N_R} w_{i,j} y_i \,(j = 1, 2, \cdots, N_s)$$

$$z_j^{\min} \le z_j^{in} \le z_j^{\max} \,(j = 1, 2, \cdots, N_s)$$

IV. 对策（技术层面－工学）

1. 新鲜水用量最小化(举例)

由10个用水过程构成的用水网络，其结构中的联接数目可达72个。如果不能满足实现条件的联接删除，则可行性联接由72个下降为40个。

过程号	$F_{i,j}$(ton /h)	有回用最小新鲜水流量	废水流量
5	$F_{4,5} = 20.0$	20.0	40.0

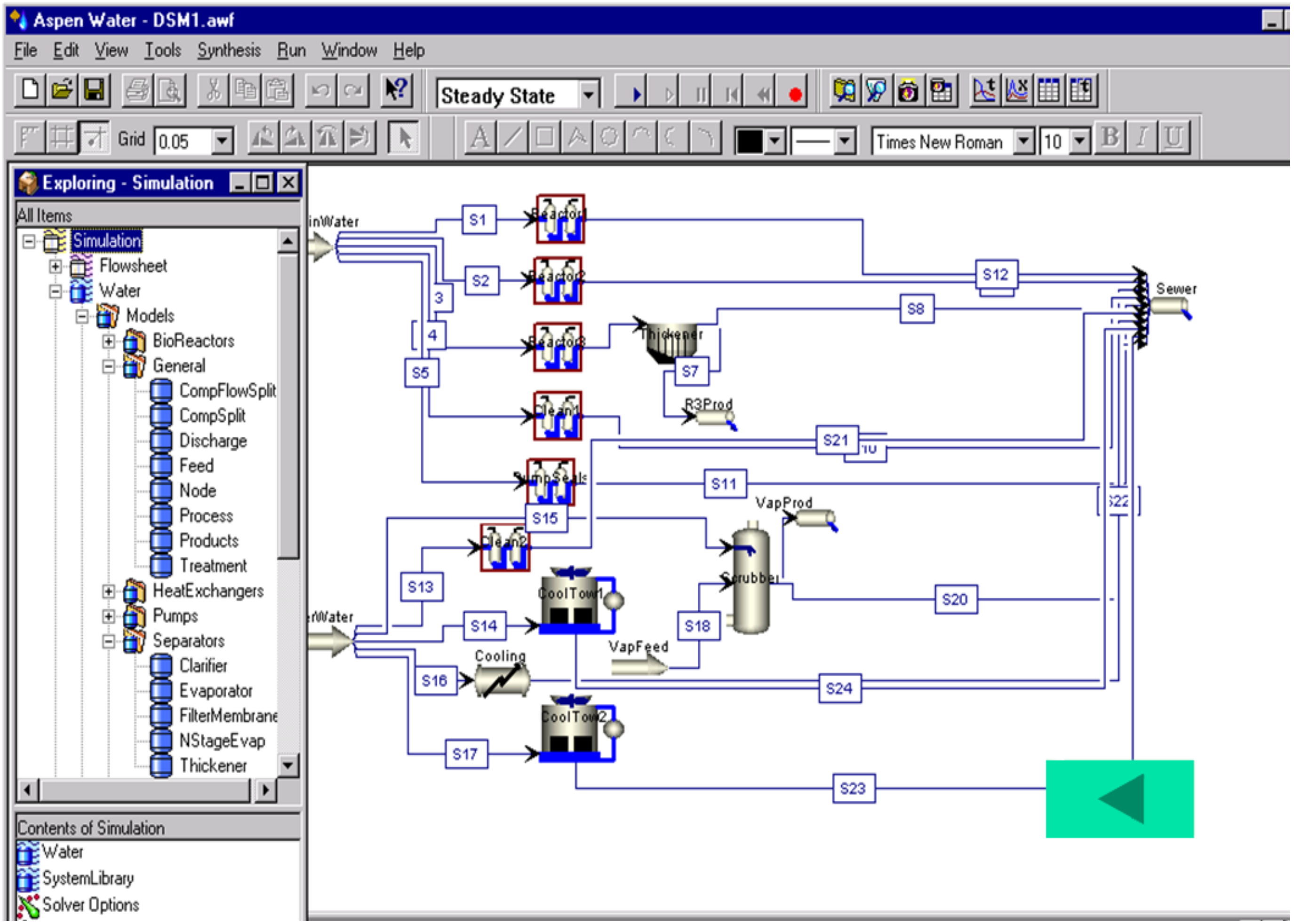
总新鲜水最小流率(ton /h) =165. 9424

最小总新鲜水耗量:

由252.4t/h下降到165.9t/h，新鲜水节省了34%以上。

IV. 对策（技术层面—工学）

优化求解 (工具—AspenWater)



什么是优化（第三个例子：微反应器设计）

Optimal Shape Design for T-shaped Microreactors with Engulfment Flow

Lin WANG, Osamu TONOMURA, Manabu KANO, Shinji HASEBE

Process Control & Process Systems Engineering Lab

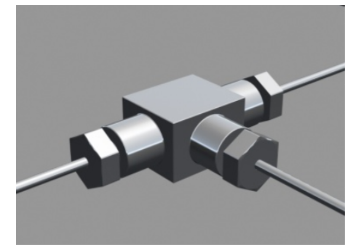
Department of Chemical Engineering

Kyoto University

Reaction in Microreactors

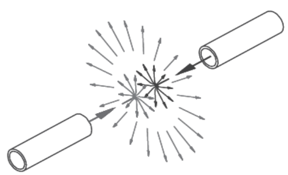
Main advantages

1. Suppression of hot spots in highly exothermic reaction
2. Suppression of by-products



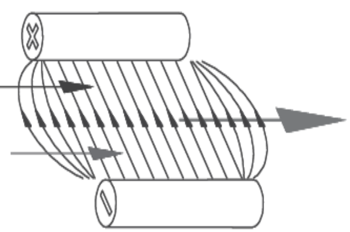
Mixing performance affects product yield

Active mixing: high energy collision (Ultrasonic, etc.)

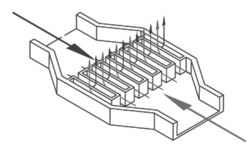


High energy collision

Forced mass transport

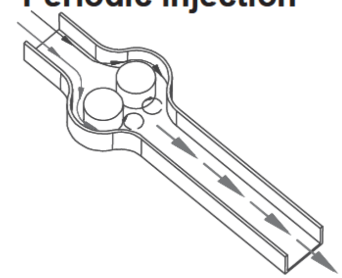


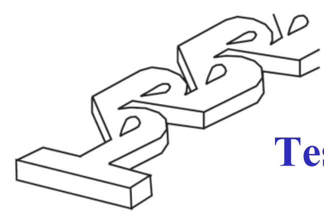
Passive mixing: the geometry of a channel must be "complicated enough "



Injection of substreams

Periodic injection





Tesla structure

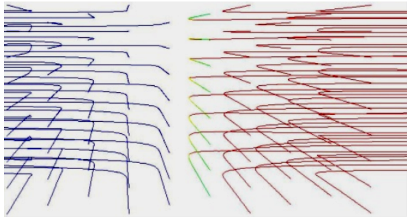
Hessel, V., et al., *Chem. Eng. Sci.*, 60, (2005)

*Hong, C. C., et al., *Lab chip*, 4, (2004)

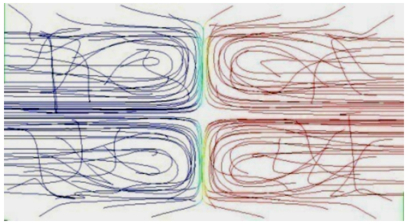
T-Shaped Microreactors (T-MRs)

- **Three types of flow.**

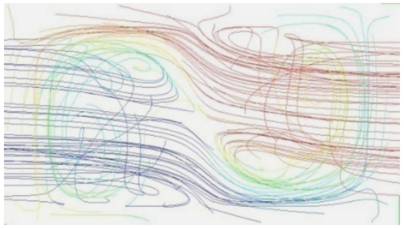
Stratified flow



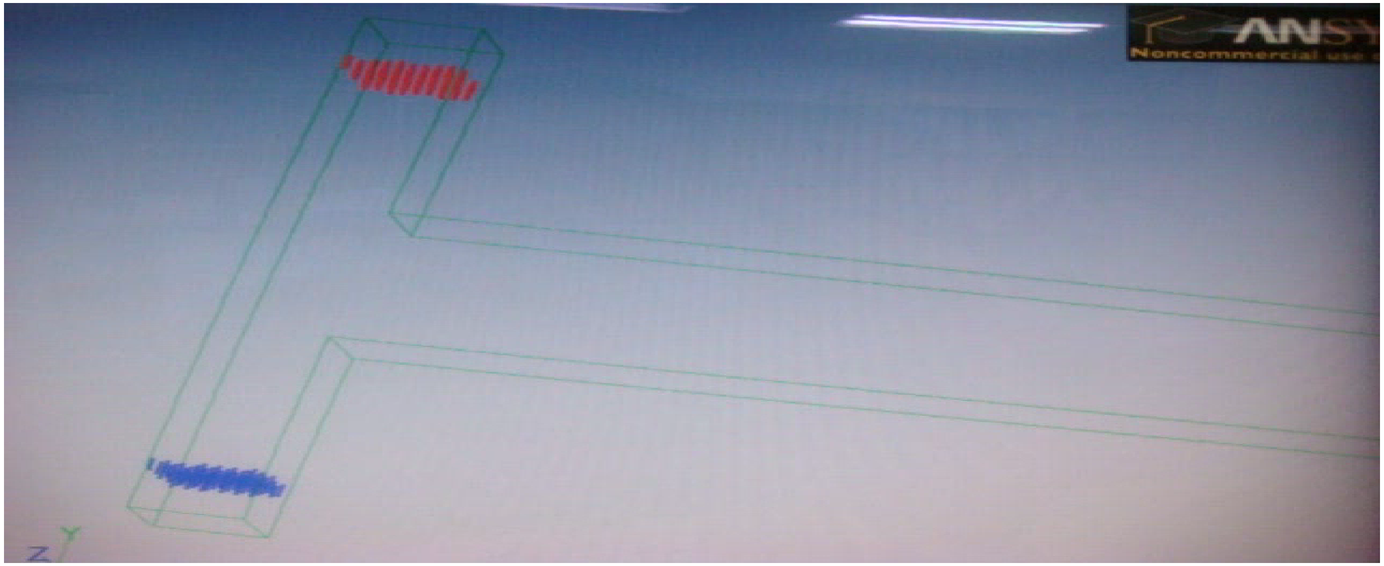
Vortex flow



Engulfment flow



Engulfment flow



Design Objective of T-MRs

- High mixing performance is achieved by engulfment flow and lead to high product yield.
- Engulfment flow is generated at high Re.
- High Re needs high pressure drop.

Design Objective	**To design a T-MR with higher product yield and lower pressure drop**
Constrains	**a simplified model**

Optimal Design Results

Max Y_R

$\boxed{W_M, H_I, L_M}$

s. t.

$$V = 4\times10^{-8}\,\mathrm{m^3s^{-1}}$$

$$\mathrm{Re}_{low} \le \mathrm{Re}$$

$$200\mu\mathrm{m} \le W_M \le 400\mu\mathrm{m}$$

$$80\mu\mathrm{m} \le H_I \le 120\mu\mathrm{m}$$

$$\Delta P \le 1.3\times10^4\,\mathrm{Pa}$$

Results

W_M^{opt}=262μm

H_I^{opt}=115 μm

L_M^{opt}=7700 μm

Optimization problems

Optimization problems

objective function

set of **unknowns** or **variables**

constraints

objective function

no objective function

multi-objective function

which we want to minimize or maximize.

1 **In a manufacturing process, we might want to maximize *the profit* or minimize *the cost*.**

2 **In fitting experimental data to a user-defined model, we might minimize the *total deviation of observed data from predictions* based on the model.**

3 **In designing an automobile panel, we might want to maximize *the strength*..**

set of **unknowns** or **variables**

essential

which affect the value of the objective function.

1. **In the manufacturing problem, the variables might include the *amounts of different resources used* or the *time spent on each activity*.**
2. **In fitting-the-data problem, the unknowns are the *parameters* that define the model.**
3. **In the panel design problem, the variables used define the *shape and dimensions* of the panel..**

constraints

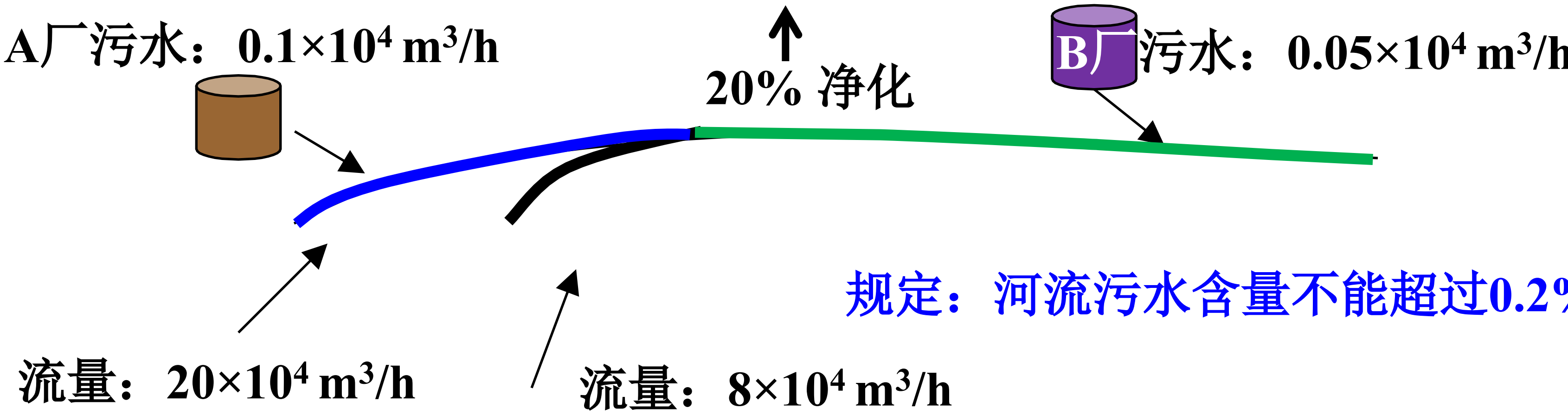
unconstrained opt.

allow the unknowns to take on certain values but exclude others.

1. **In the manufacturing problem, it does not make sense to spend a negative amount of time on any activity, so we constrain all the "time" variables to be non-negative.**
2. **In the panel design problem, we would probably want to limit the *weight* of the product and to constrain its *shape.***

环境保护问题

从第一化工厂排出的工业污水流到第二化工厂以前，有20%可以自然净化。



规定：河流污水含量不能超过0.2%

已知：处理污水成本：A厂 1000元 / 10^4m^3 B厂 800元 / 10^4m^3

问题：在满足环保要求的前提下，各个厂处理多少污水，才能使该公司处理污水的费用最小。

环境保护问题

x_1、x_2——分别代表工厂A和工厂B处理污水的数量(10^4m^3)。

目标函数：$\min z=1000x_1+800x_2$

约束条件：

第一段河流（兰色）：

$(0.1-x_1)/20 \leq 0.2\%$

第二段河流（绿色）：：

$[0.8(0.1-x_1)+(0.05-x_2)]/28 \leq 0.2\%$

此外有：

$x_1 \leq 0.1$； $x_2 \leq 0.05$

化简有：

优化问题的数学模型

$$\boxed{\min\ (\max)\ \ f(x)}$$

$$\boxed{\text{s. t.}}\qquad \begin{aligned} g(x) &\geq 0 \\ h(x) &= 0 \end{aligned}$$

式中 $g(x)=(g_1(x),\ g_2(x),\ \ldots,\ g_m(x))^{\mathrm{T}}$

$h(x)=(h_1(x),\ h_2(x),\ \ldots,\ h_l(x))^{\mathrm{T}}$

$x=(x_1,\ x_2,\ \ldots,\ x_n)^{\mathrm{T}}$

等式约束：$h(x)$	不等式约束：$g(x)$
化工过程　热力学、动力学	过程操作安全生产条件
➢物料平衡方程	➢压力上下限
➢热量平衡方程	➢温度上下限
➢动量平衡方程	➢人力、物力、设备处理能力

决策变量	状态变量
决策者根据目标和约束条件的要求而确定	描述过程或系统的特征或行为
➢ 选择那些易观察、能检测、能控制的变量	➢ 其值不能任意选取

决策变量一经确定，状态变量也随之确定

在确定状态变量和决策变量时必须遵循以下原则

状态变量数目 ＝ 状态方程数目

变量总数 – 状态方程数 ＝ 决策变量数

★ 决策变量数 又称为优化问题的自由度

❖ 难易程度、0、1、大、小