# Novel method for reducing resistance and energy consumption for heating and cooling piping distribution system

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# 供热制冷能源输配系统减阻降耗新方法

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9 March,2021

➢ 输配减阻方向学位论文

# Research Theses (on drag reduction) Angui Li's Group

| Serial<br>序号 | Thesis title<br>论文题目 | Author<br>作者 | Supervisor<br>导师 Angui LI | Graduation time<br>学位授予时间 | Degree<br>学位层次 |
|---|---|---|---|---|---|
| 1 | 通风管道中粒子沉积规律的数值模拟与实验研究 | 张金萍 | 李安桂 | 2006 | 博士 PhD |
| 2 | 通风管道局部构件阻力系数的实验和数值模拟研究 | 李涛 | 李安桂 | 2005 | 硕士 MSc |
| 3 | 通风管道局部构件阻力系数及减阻方法研究 | 惠荣娜 | 李安桂 | 2007 | 硕士 MSc |
| 4 | 供热、制冷管道弯头和三通的近距离耦合管内流动2DPIV实验及CFD研究 | 张新记 | 李安桂 | 2008 | 硕士 MSc |
| 5 | 弯头耦合三通降阻PIV实验及CFD研究 | 陈磊 | 李安桂 | 2009 | 硕士 MSc |
| 6 | 空调通风管道弯头的降阻整流方法 | 鱼晟睿 | 李安桂 | 2015 | 硕士 MSc |
| 7 | 基于相邻条件下的通风空调管道阻力特性及减阻方法 | 赵建勋 | 李安桂 | 2016 | 硕士 MSc |

# Research Theses (on drag reduction) Angui Li’s Group

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|---|---|---|---|---|---|
| 8 | 通风空调管道分流T形三通变径消涡降阻方法 | 陈仕扩 | 李安桂、高然 | 2017 | 硕士 MSc |
| 9 | 地面辐射采暖分集水器减阻及结构优化模拟 | 李成 | 李安桂 | 2018 | 硕士 MSc |
| 10 | 基于湍流耗散率控制的分流三通减阻方法研究 | 方智宇 | 高然 | 2019 | 硕士 MSc |
| 11 | 基于“仿生”的通风空调管道三通减阻方法研究 | 刘凯凯 | 李安桂、高然 | 2019 | 硕士 MSc |
| 12 | 通风空调管道系统中渐缩、渐扩管段的减阻优化 | 范孟亮 | 李安桂 | 2020 | 硕士 MSc |
| 13 | 基于能量耗散率控制的风阀阻力特性优化研究 | 文诗豪 | 高然 | 2020 | 硕士 MSc |
| 14 | 多分支流体分布系统流动特性与减阻优化 | 张婉卿 | 李安桂、周敏 | | 博士 PhD |

# 报告内容 Content

Drag reduction of HVAC piping distributi on system

通风空调输配系统减阻

# 1、背景及进展 Background and progress

通风空调管道系统的阻力问题关乎工业建筑安全生产（加速管壁磨损），还可诱发气动噪声污染、增加管道积灰及有害微生物沉积、引起风机喘振等，引发事故。

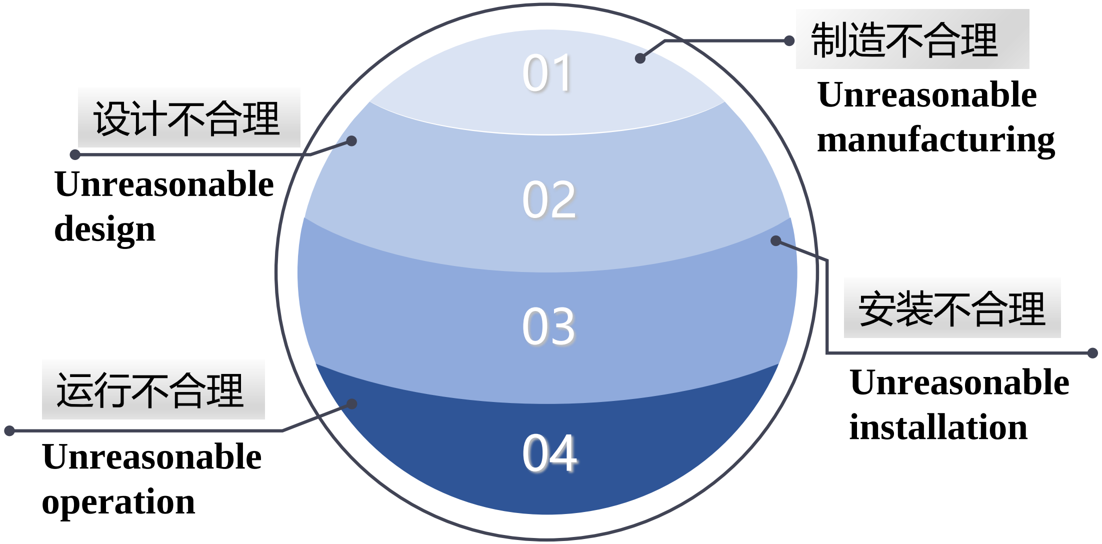
**The resistance of the HVAC piping system is also pertinent to the safe production of industry (eg. accelerate the worn of the duct interior). Also, it can induce aerodynamic noise, increase pipeline fouling and harmful microorganism deposition, etc., causing accidents.**

目前，中国建筑能耗约占总能耗20%，其中通风空调阻力占建筑能耗15%～30%。局部阻力占管道系统总阻力达到50%以上。

**At present, building energy consumption in China accounts for more than 20% of the total energy consumption, of which the resistance of HVAC system accounts for 15% to 30% of the building energy consumption. The local drag resistance contributes to more than 50% of the total resistance of the pipeline system.**

"错综复杂"的通风空调管道 "Intricated" HVAC ducts

# 1、背景及进展 Background and progress




通风空调管道阻力过大的影响因素
Influencing factors of excessive resistance for HVAC ducts

- 优化通风空调管道局部构件（弯头、三通、变径等），降低阻力，提高能源利用率，具有现实、重要意义。

**It is of great practical significance to optimize the local components for HVAC ducts (eg. elbows, tees, connectionning parts, etc.), to reduce drag resistance and improve energy efficiency.**

# 1、背景及进展 Background and progress

## ➢ 沿程阻力损失 Friction losses

风管沿程摩擦损失$P_m$计算:

Resistance loss along the duct:

$$\Delta P_m = \Delta p_m \cdot l$$

单位管长沿程摩擦阻力，**可按下式**计算:

Specific frictional resistance:

$$\Delta p_m = \frac{\lambda}{d_e} \cdot \frac{V^2 \rho}{2}$$

**矩形**风管当量直径，可按下式计算:

Equivalent diameter of rectangular duct:

$$d_e = \frac{2ab}{a+b}$$

摩擦阻力系数可按柯列勃洛克·怀特式计算:

Friction factor can be calculated according to Colebrook's equation:

$$\frac{1}{\sqrt{\lambda}} = -2\,log\left(\frac{K}{3.71 d_e} + \frac{2.51}{Re\sqrt{\lambda}}\right)$$

莫迪公式:

Moody equation:

$$\lambda = 0.0055\left[1+\left(20000\frac{K}{d} + \frac{10^6}{Re}\right)^{\frac{1}{3}}\right]$$

# 1、背景及进展 Background and progress

尼古拉兹光滑区： $$\frac{1}{\sqrt{\lambda}} = 2log\left(Re\sqrt{\lambda}\right)\text{-}0.8$$

Nikuradse hydraulically smooth zone:

尼古拉兹粗糙区： $$\frac{1}{\sqrt{\lambda}} = 2log\frac{r_0}{K} + 1.74$$

Nikuradse hydraulically rough zone:

粗糙区希弗林松公式： $$\lambda = 0.11\left(\frac{K}{d}\right)^{0.25}$$

Щифринсон formula for hydraulically rough zone:

光滑区布拉修斯公式： $$\lambda = \frac{0.3164}{Re^{0.25}}$$

Blasius formula for hydraulically smooth zone :

紊流光滑区： $$2000 < Re \leq 0.32\left(\frac{K}{d}\right)^{1.28}$$

Turbulent smooth zone :

紊流过渡区： $$0.32\left(\frac{K}{d}\right)^{1.28} < Re \leq 1000\left(\frac{K}{d}\right)$$

Turbulent transition zone :

紊流粗糙区： $$Re > 1000\left(\frac{K}{d}\right)$$

Turbulent rough zone:

- **局部阻力损失公式**

 Formula of local resistance loss

 局部压力损失（Pa）：

 Local pressure loss

$$\Delta P_j = \zeta\frac{V^2\rho}{2}$$

**局部阻力系数可**评价阻力特性及减阻效果

The local resistance coefficient can be used to evaluate the resistance characteristics and drag reduction effect.

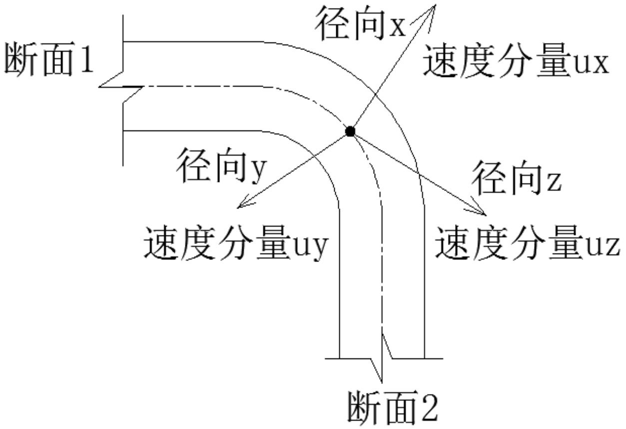
# 1、背景及进展　Background and progress

➢ **涡旋引起的能量耗散**　Energy dissipation caused by vortex

**耗散**项的体积分形式及其向量方向:

The volume fraction form and vector direction of dissipation term

$$E=-\iiint_{V_{1-2}}\Phi\, dV=-\mu\iiint_{V_{1-2}}\left[\left(\frac{\partial u_z}{\partial x}+\frac{\partial u_x}{\partial z}\right)^2+\left(\frac{\partial u_z}{\partial y}+\frac{\partial u_y}{\partial z}\right)^2+\left(\frac{\partial u_x}{\partial y}+\frac{\partial u_y}{\partial x}\right)^2\right]dV$$




局部构件阻力问题实质是**气流涡旋作用下的能量耗散**（机械能转化为内能过程，耗散量越大，出口机械能越小）。控制气流涡旋，即实现减阻降耗。

The problem of local component resistance is essentially **the energy dissipation under the influence of the air vortex** (the process of converting mechanical energy into internal energy, the greater the dissipation, the smaller the outlet mechanical energy). Control the vortex of the airflow to reduce resistance and consumption.

# 1、背景及进展　Background and progress

从行业视角来看，改变边界条件，即局部构件内涡旋特性。改变耗散项积分的边界条件V1-2（改变弧线结构，设置导流叶片等），控制涡旋强度及作用范围，减小速度梯度，降低ϕ值，降低局部阻力损失。

From the perspective of the industry, change the boundary conditions is to change the vortex characteristics within the local component. Alter the boundary condition V1-2 of the integral of the dissipation term (vary the arc structure, set the turning vane, etc.), control the vortex intensity and its range, reduce the local resistance loss by decreasing the velocity gradient and the value of φ .

**通**风空调管道系统局部阻力系数：英国D.S.Miler、**美国**ASHRAE**和前**苏联通过实验过程**得出了常用**风管尺寸下的局部阻力系数。

The local resistance coefficient of the HVAC piping system: D.S.Miler in the UK, ASHRAE in the USA and the FSU have obtained the local resistance coefficient under common duct sizes through the experiments.

**在20世纪80年代，我国**风管局部阻力系数采用前苏联的数据。目前，风管局部构件局部**阻力系数**则采用美国ASHRAE**的**Fundamentals Handbook**中**DUCT DESIGN。

In the 1980s, the local resistance coefficient of ducts in our country adopted the data of the FSU. At present, the local resistance coefficient of the local components of the duct adopts DUCT DESIGN in the Fundamentals Handbook of ASHRAE in the USA.

# 1、背景及进展 Background and progress

一些学者借鉴国外有关资料的基础上，对通风空调管道局部阻力系数进行了研究或者分析总结。

Some scholars have studied or analyzed the local resistance coefficient of HVAC pipes based on relevant foreign materials.

**根据减阻区域及作用原理的不同，**现有管道局部构件减阻研究方面：

In light of the differences in drag reduction area and working mechanisms, the current research on drag reduction of local pipeline comprises:

（1）导流叶片减阻 Turning vane drag reduction

（2）**整流器减阻** Rectifier drag reduction

（3）**管道弧面形式减阻** Duct arc surface drag reduction

（4）**其他**类型减阻 Other types of drag reduction

# 1、背景及进展 Background and progress

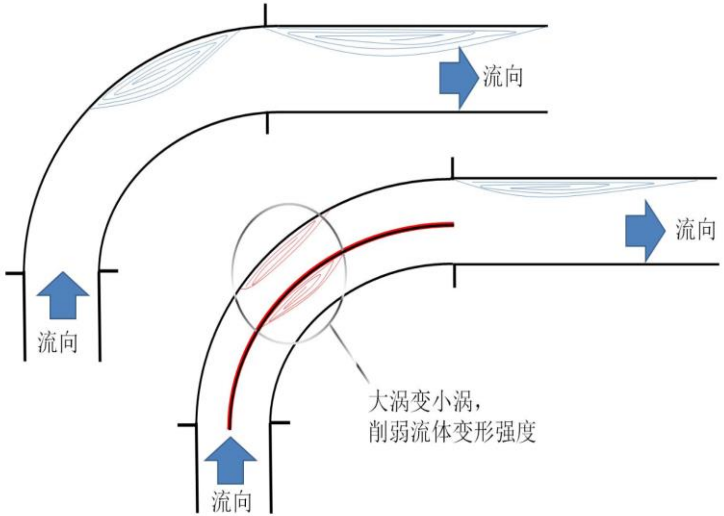
## （1）导流叶片减阻 Turning vane drag reduction

**通**过额外的固体壁面对流体涡旋进行分割，大涡旋分解为小涡旋，降低局部构件中流体阻力。

The large vortices are decomposed into small ones through sundering of additional solid wall towards fluid vortex, which reduces the fluid resistance in the local components.

**在**涡旋分离点附近添加导流叶片，能够有效消弱涡旋**的作用范**围。

Adding turning vanes near the separation point of the vortex can effectively weaken the range of action of the vortex.




导流叶片的设置需要结合局部构件内的涡旋位置、强度进行。

The setting of the turning vanes needs to be combined with the position and strength of the vortex in the local components.

现有研究大都针对大规格尺寸风管，对小规格风管较少涉及。

Existing researches mostly focus on large-size air ducts, and seldom involve small-size ones.

# 1、背景及进展　Background and progress

（2）整流器减阻 Rectifier drag reduction

构件内的阻力损失由分离流引起的涡旋，其作用范围可达15D；而二次流的作用范围可达50D。

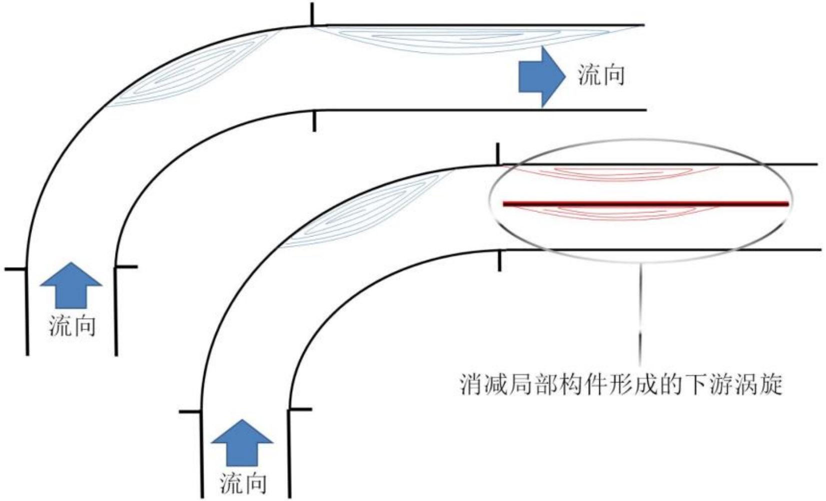
The resistance loss in the component is caused by the vortex which is induced by separation flow, and its action range can reach to 15D; and the action range of the secondary flow can reach to 50D.

**整流器减阻是快速消减局部构件下游**涡旋达到减阻。

Rectifier drag reduction can reduce the downstream vortex of local components quickly to achieve drag reduction.

**整流器重在"整流"而不一定"减阻"，整流器本身会引起阻力。**

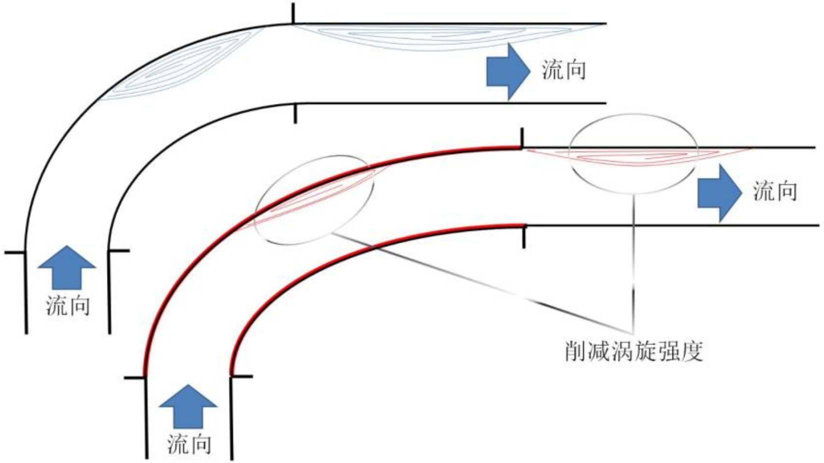
The rectifier focuses on "rectification" but not necessarily "drag reduction", the rectifier itself will cause resistance.



## （3）管道弧面形式减阻
## Duct arc surface drag reduction

**改**变曲率半径、弧度角、截面积等。通过管道局**部构件**变形，消弱离心力、压强梯度强度，降低涡旋强度，达到减阻目的。

Change the radius of curvature, radian angle, cross-sectional area, etc. Through the deformation of the local components of the pipe, the centrifugal force and the pressure gradient strength are weakened, and the vortex strength is reduced to achieve the purpose of drag reduction.




**注意工程适用性：如改**变弯头的曲率半径能够大幅度减少弯头过流局部阻力，但是建筑空间有限，**局部构件有**较大体积影响安装。

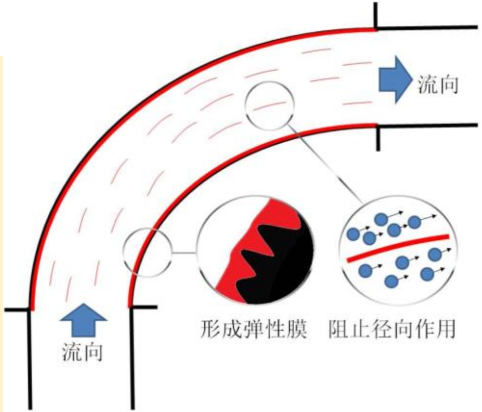
Pay attention to engineering applicability: If the radius of curvature of the elbow is changed, the local resistance of the elbow can be greatly reduced, but the construction space is limited, and the large volume of local components affects the installation.

# 1、背景及进展　Background and progress

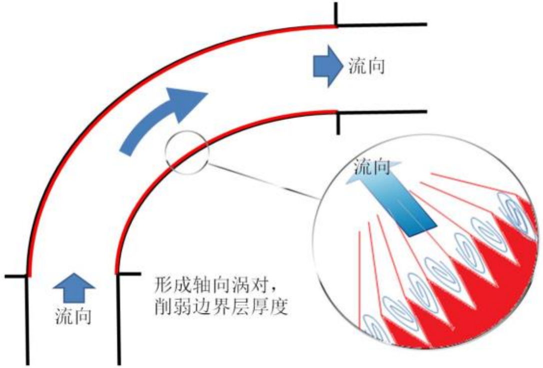
（4）其他类型减阻　Other types of drag reduction

**管道添加高分子减阻**剂、管道壁面加工轴向V **型沟槽减阻、表面添加高分子涂料减阻等。多**见于石油**管**线长距离输送。在通风空调领域（减阻剂减阻等）应用有待于进一步研究。

Adding polymer drag reducer, processing the axial V-shaped groove on the wall surface, adding polymer coating to the surface, etc. are more common in long-distance transportation of oil pipelines. In the field of HVAC (drag reducing agent, etc.) applications need to be further studied.




减阻剂减阻
Drag reducing agent




凹槽表面减阻
Drag reduction on groove surface

# 报告内容 Content

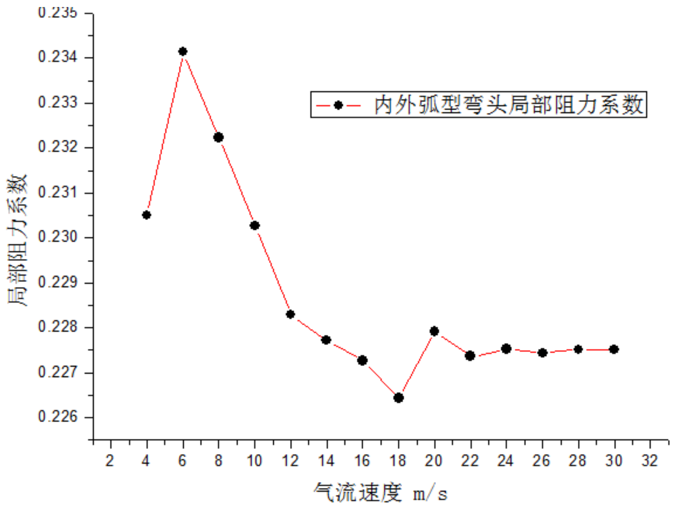
Drag reduction of HVAC piping distributi on system

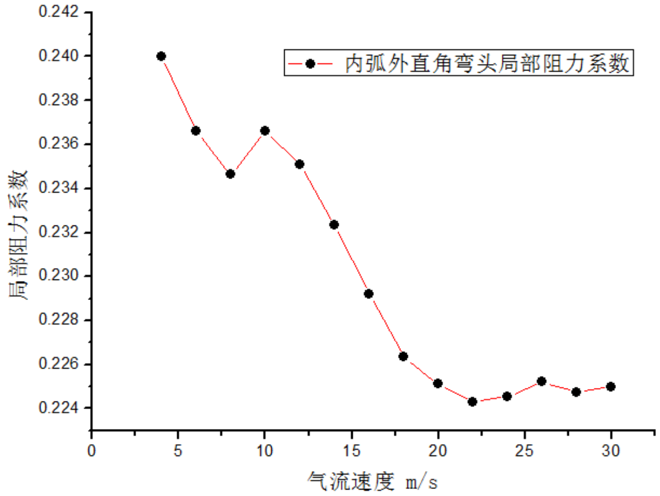
通风空调输配系统减阻

# 2、减阻理论及技术 Drag reduction theory and technology

➢ **空气流速对矩形风管弯头损失影响**

The influence of air velocity on the local resistance loss of rectangular duct elbow



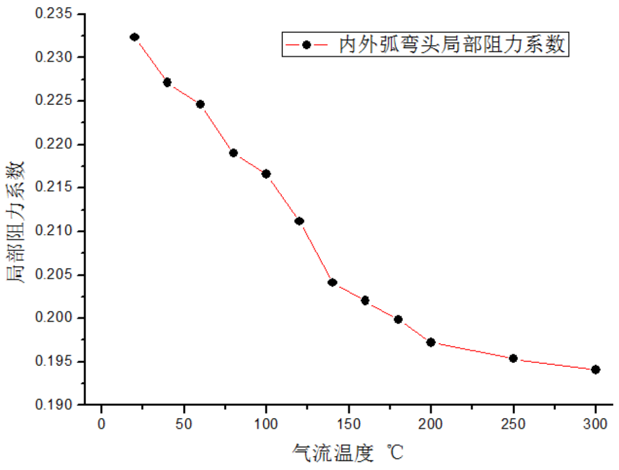

阻力损失各项影响因素的数值模拟

Numerical simulation of various influencing factors of resistance loss

# 2、减阻理论及技术 Resistance reduction theory and technology

## ➢ 空气温度对矩形风管弯头损失的影响

The influence of air temperature on the local resistance loss of rectangular duct elbow



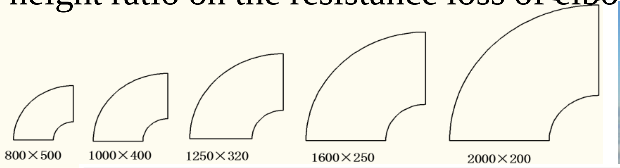

物理模型分别采用内外弧型及内弧外直角型弯头。在现代建筑中，风管内空气速度一般在3~15m/s，空气温度一般在15~30℃之间。数值模拟中为了找出影响的规律性，对工况进行不同程度的扩展。

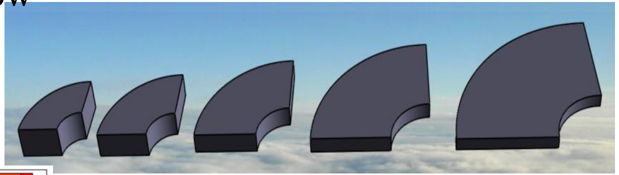
The physical model adopts inner and outer arc type as well as inner and outer right angle elbow respectively. In modern buildings, the air velocity in the duct is generally 3~15m/s, and the air temperature is generally between 15~30℃. In the numerical simulation, in order to find out the regularity of the influence, the working conditions were expanded to different degrees.

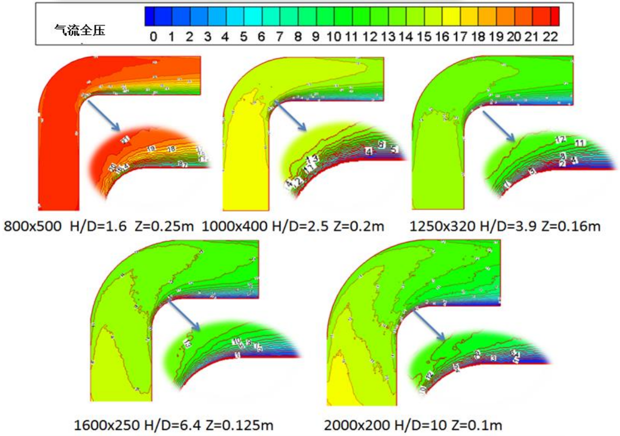
# 弯头阻力损失各项影响因素的数值模拟
Numerical simulation of various influencing factors of elbow resistance loss

## ➢ 矩形风管宽高比对弯头阻力损失的影响
The effect of rectangular duct width-to-height ratio on the resistance loss of elbow

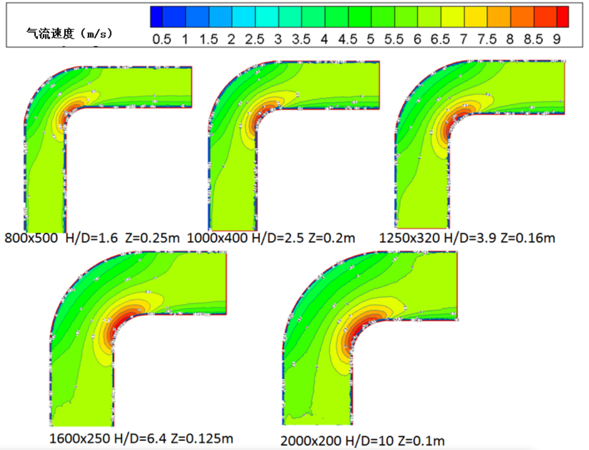
**不同宽高比弯头模型**
**Elbow model with different aspect ratio**



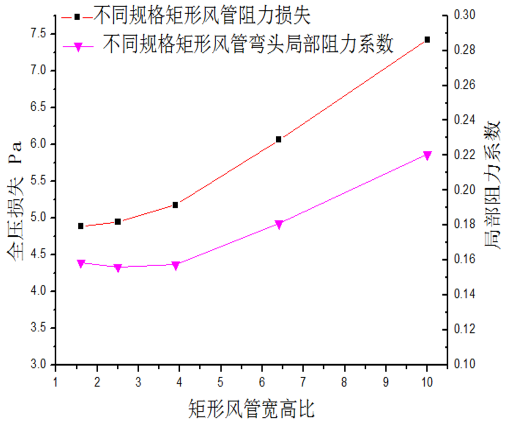






**不同宽高比弯头气流全压云图**
**Contour for full pressure of different aspect ratio elbows**




**不同宽高比弯头气流速度云图**
**Contour for airflow velocity of elbows with different aspect ratios**




**不同宽高比弯头阻力损失变化趋势图**
**Chart of resistance loss trend of elbows with different aspect ratios**

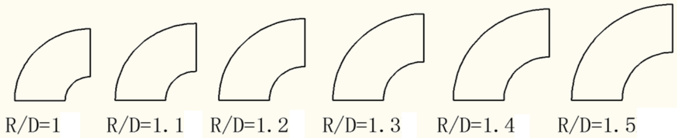
# 弯头阻力损失各项影响因素的数值模拟

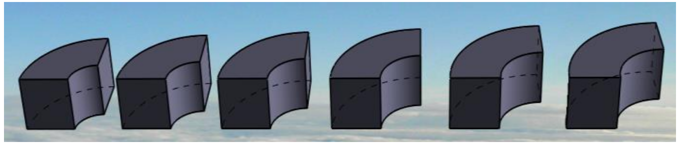
Numerical simulation of various influencing factors of elbow resistance loss

## ➢ 矩形风管弯头曲率半径对弯头阻力损失的影响

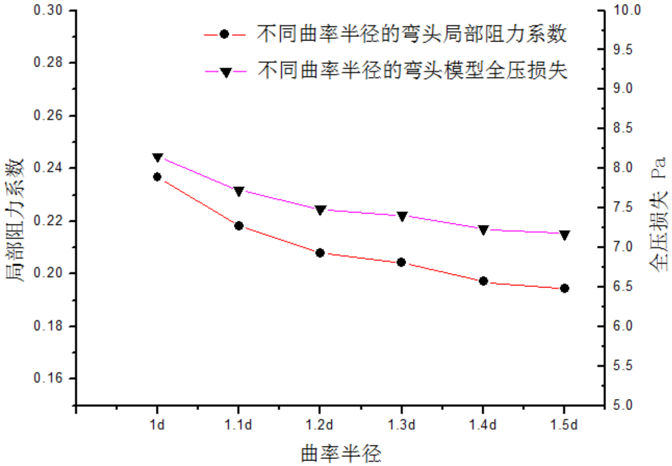
The influence of the radius of curvature of the rectangular duct elbow on the resistance loss of the elbow

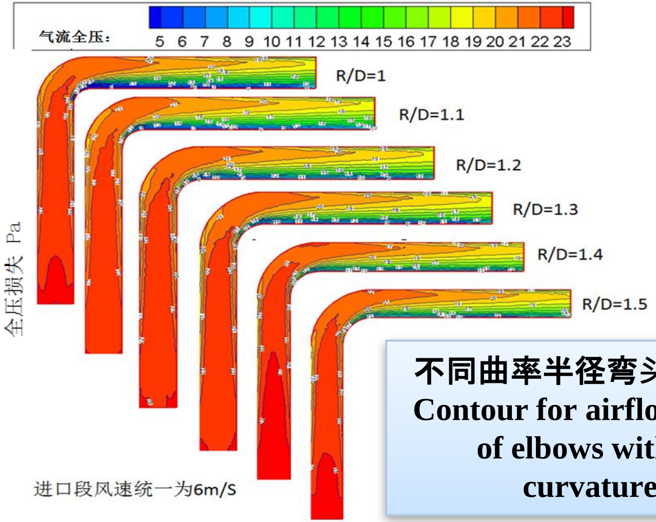
**不同曲率半径弯头模型**
**Elbow model with different radius of curvature**



**不同曲率半径弯头阻力损失变化趋势图**
**Chart of resistance loss trend of elbows with different curvature radius**

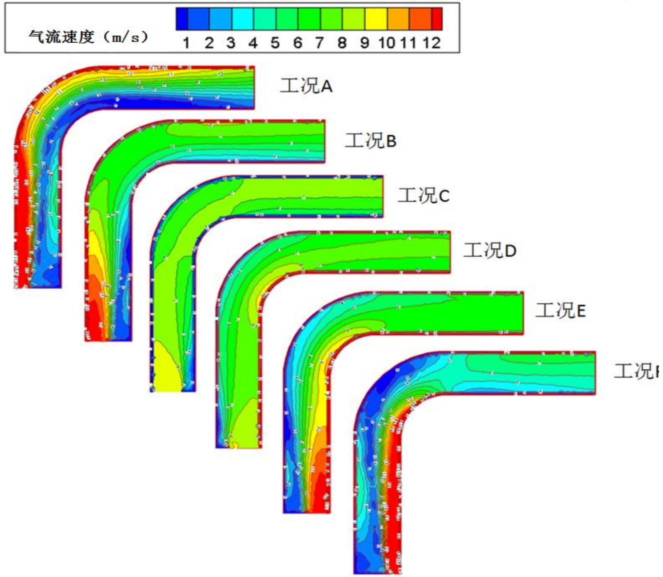


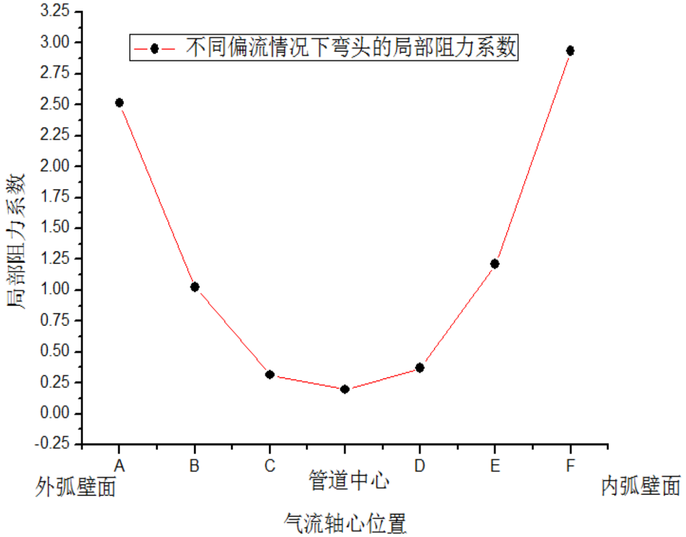

**不同曲率半径弯头气流全压云图**
**Contour for airflow full pressure of elbows with different curvature radius**

# 弯头阻力损失各项影响因素的数值模拟
Numerical simulation of various influencing factors of elbow resistance loss

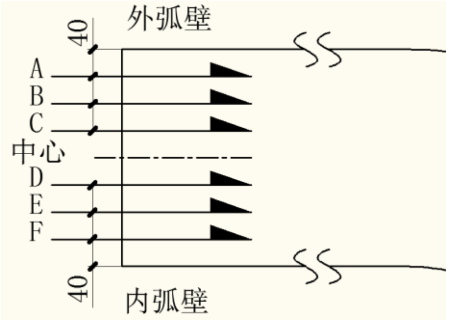
## ➢ 管内不均匀流（管内偏流）对矩形风管弯头损失的影响
The influence of uneven flow in the duct (internal drift) on the loss of rectangular duct elbow




**不同偏流工况下弯头的气流速度云图**
**Contour for air velocity of elbows under different drift conditions**



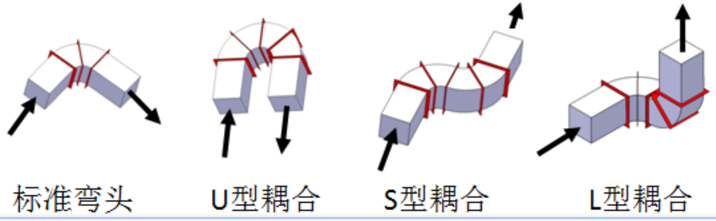

**不同偏流工况下弯头的局部阻力系数**
**The local resistance coefficient of elbows under different drift conditions**



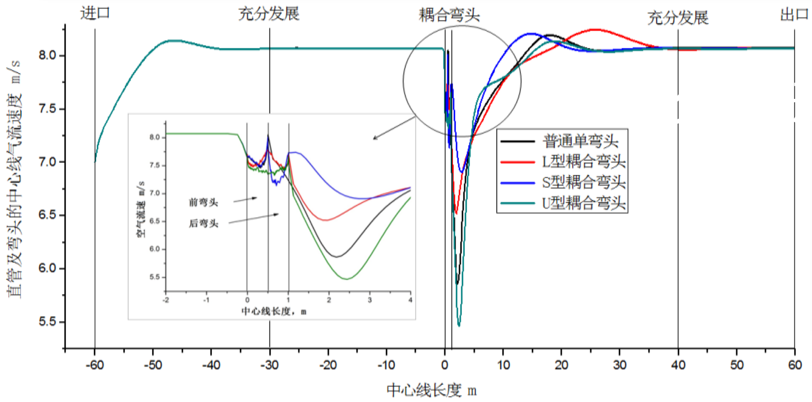

**不同偏流工况示意图**
**Schematic diagram of different drift conditions**

## ➢ 矩形风管弯头近距离相互耦合对气流组织的影响

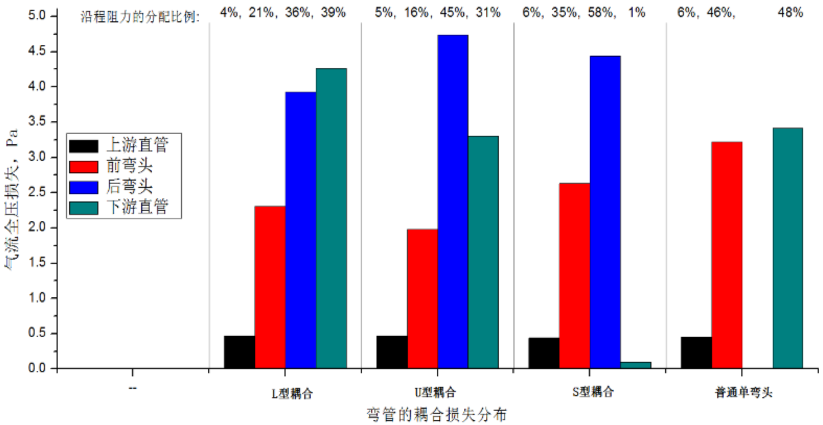
Influence of coupling of rectangular duct elbows at close distance on air distribution




**不同弯头耦合方式示意图**
**Schematic diagram of different elbow coupling modes**




**不同耦合弯头中心线气流速度变化图**
**Diagram for airflow velocity change of center line of different coupling elbows**

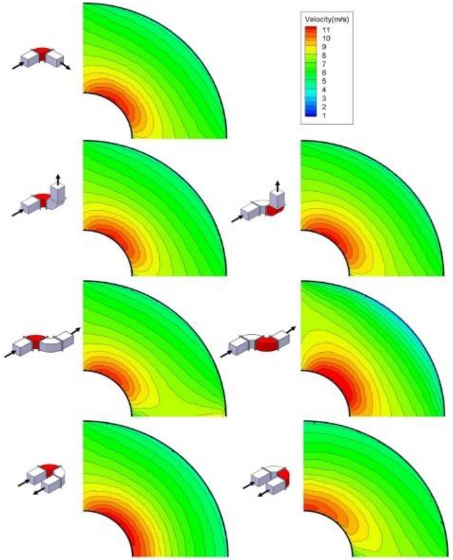



**不同耦合弯头阻力损失分布图**
**Diagram for resistance loss distribution of different coupling elbows**

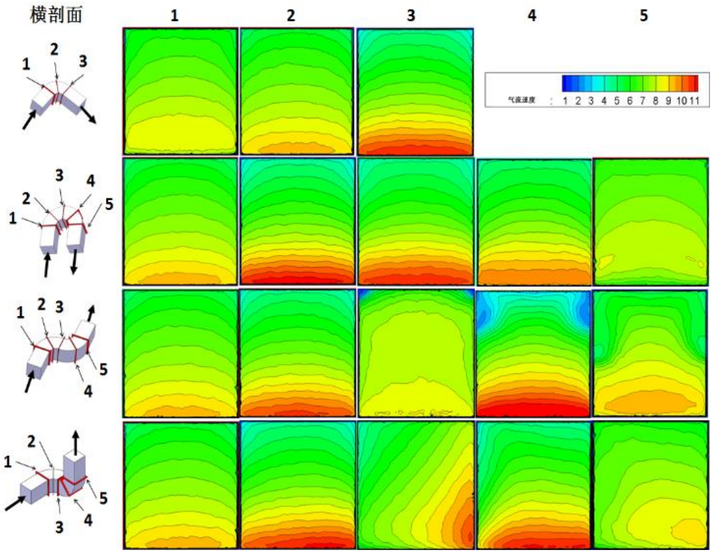
# 弯头阻力损失各项影响因素的数值模拟
Numerical simulation of various influencing factors of elbow resistance loss

## ➢ 矩形风管弯头近距离相互耦合对气流组织的影响

Influence of coupling of rectangular duct elbows at close distance on air distribution

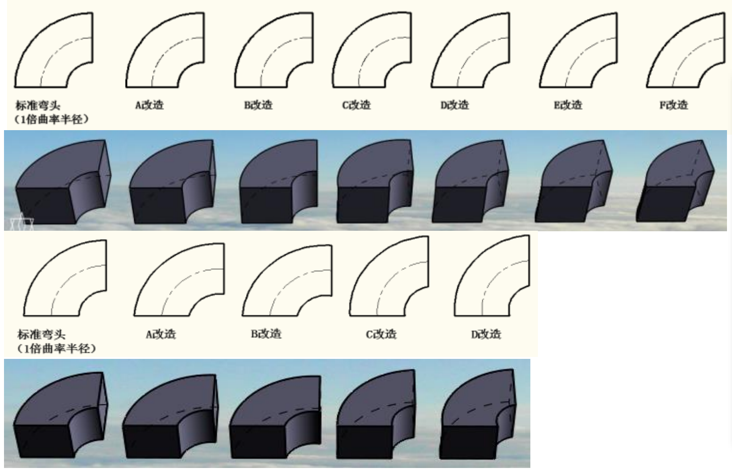



轴线平行方向速度云图
**Contour for speed of parallel to the axis**




轴线垂直方向速度云图
**Contour for velocity of vertical direction of axis**

# 弯头弧线的优化（中轴线） Optimization of the arc of the elbow (central axis)




**不同中轴线典型改造方案模型**
**Models of typical reconstruction schemes for different central axis**

**不同中轴线典型改造方案降阻效果表**
**Table of resistance reduction effects of typical transformation schemes for different central axis**

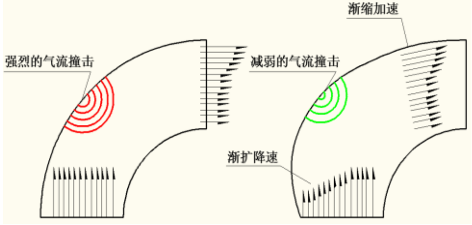
| | 气流速度 | 全压损失 | 相比弯头增减比率 |
|---|---|---|---|
| 弯头 | 6 | 8.15 | - |
| A | 6 | 8.20 | ↑1.03% |
| B | 6 | 8.23 | ↑1.51% |
| C | 6 | 8.33 | ↑1.75% |
| D | 6 | 8.04 | ↓1.97% |
| E | 6 | 8.06 | ↓1.52% |
| F | 6 | 8.07 | ↓1.37% |

| | 气流速度 | 阻力系数 | 相比弯头增减比率 |
|---|---|---|---|
| 弯头 | 6 | 0.25 | - |
| A | 6 | 0.22 | ↓5.15% |
| B | 6 | 0.25 | ↑5.69% |
| C | 6 | 0.24 | ↑1.95% |

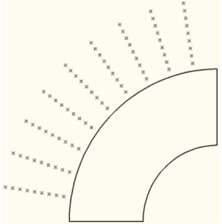
中轴线的改造，实质上就是三条弧线的整体同步改造。否则，中轴线的改造就没有意义。

**The transformation of the central axis is essentially the overall simultaneous transformation of the three arcs. Otherwise, the transformation of the central axis is meaningless.**

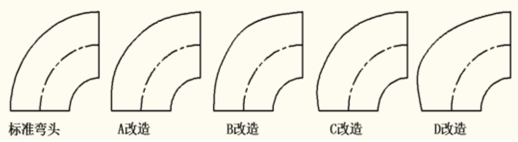
# 弯头弧线的优化（外弧线） Optimization of the arc of the elbow (outer arc)

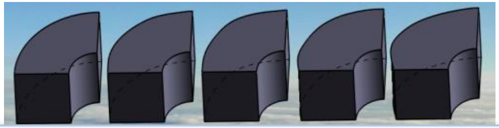



**外弧线改造构想示意图**
**Schematic diagram of the reconstruction concept of the outer arc**



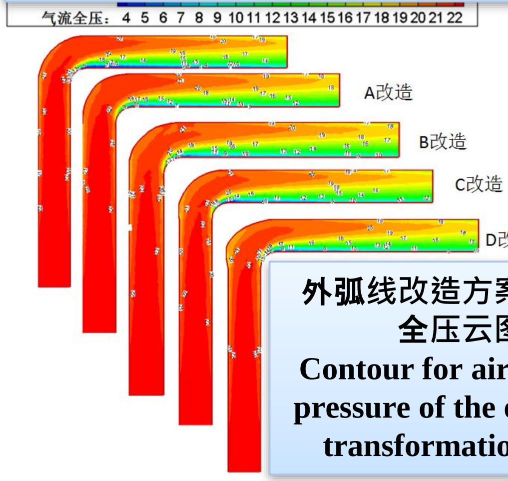
**外弧线改造的点矩阵**
**Point matrix for outer arc transformation**



**弯头外弧线改造方案示意图**
**Schematic diagram of the reconstruction plan for the outer arc of the elbow**

外弧线改造的核心，在于改造后，降阻效果能否大于变径所带来的阻力损失。
The core of the outer arc transformation is whether the resistance reduction effect after the transformation is greater than the resistance loss caused by the diameter change.

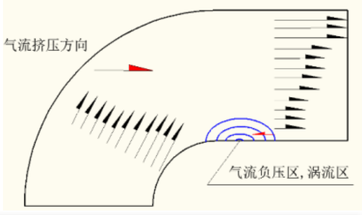



**外弧线改造方案的气流全压云图**
**Contour for airflow full pressure of the outer arc transformation plan**

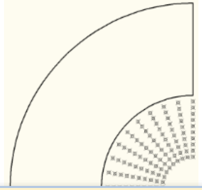
| | 气流速度 | 全压损失 | 相比弯头增减比率 |
|---|---|---|---|
| 弯头 | 6 | 8.15 | — |
| A | 6 | 7.79 | ↓**6.53%** |
| B | 6 | 8.10 | ↓0.91% |
| C | 6 | 8.07 | ↓1.32% |
| D | [illegible] | [illegible] | [illegible] |

**弯头外弧线优化改造降阻效果对比表**
**Table of drag reduction effect comparison of elbow outer arc optimization transformation**

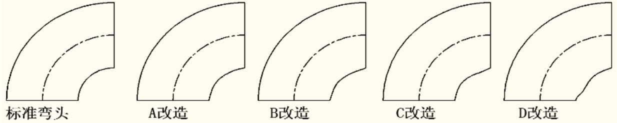
# 弯头弧线的优化（内弧线） Optimization of the arc of the elbow (inner arc)

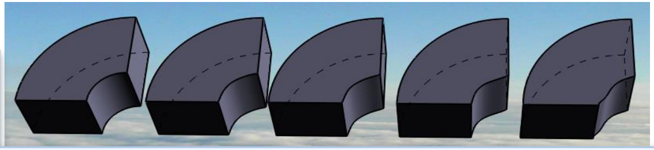



**内弧线改造构想示意图**
**Schematic diagram of the reconstruction concept of the inner arc**



**内弧线改造的点矩阵**
**Point matrix for inner arc transformation**

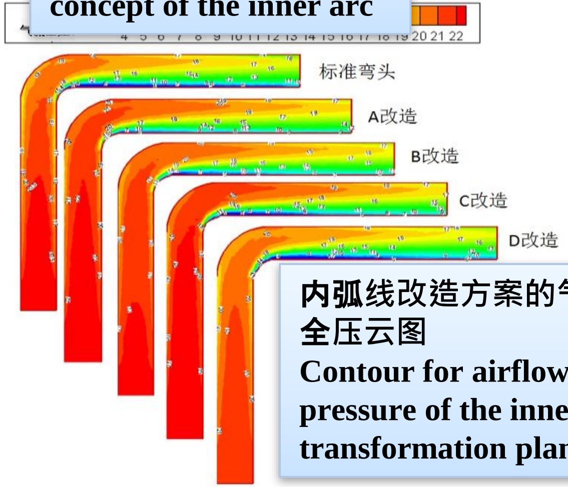


**弯头内弧线改造方案示意图**
**Schematic diagram of the reconstruction plan for the inner arc of the elbow**

内弧线改造的核心，在于改造后，是否能够消除弯头出口段附近的气流涡旋负压区。

The core of the inner arc transformation is whether it can eliminate the negative pressure area of the vortex near the exit section of the elbow after the transformation.

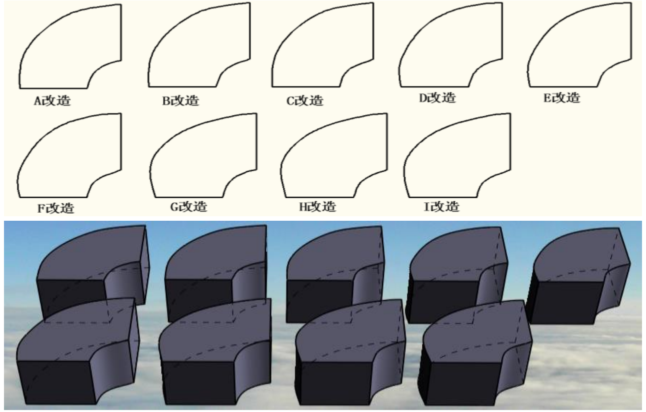



**内弧线改造方案的气流全压云图**
**Contour for airflow full pressure of the inner arc transformation plan**

| | 气流速度 | 全压损失 | 阻力系数 | 相比弯头增减比率 |
|---|---|---|---|---|
| 弯头 | 6 | 8.15 | 0.24 | — |
| A | 6 | 7.82 | 0.22 | ↓5.95% |
| B | 6 | 8.08 | 0.23 | ↓1.23% |
| C | 6 | [illegible] | [illegible] | [illegible] |

**弯头内弧线优化改造降阻效果对比表**
**Table of resistance reduction effect comparison of elbow inner arc optimization transformation**

# 弯头弧线的优化（综合内外弧）
## Optimization of elbow arc (comprehensive inner and outer arc)




弯头综合内外弧改造典型方案示意图
**Schematic diagram of a typical plan for comprehensive inner and outer arc elbow**

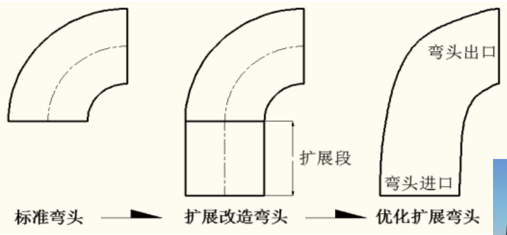
| | 气流速度 | 全压损失 | 相比弯头增减比率 |
|---|---|---|---|
| 弯头 | 6 | 8.15 | — |
| A | 6 | 8.00 | ↓2.48% |
| B | 6 | 7.91 | ↓4.29% |
| C | 6 | 8.12 | ↓0.46% |
| D | 6 | 7.64 | ↓9.21% |
| E | 6 | [illegible] | [illegible] |

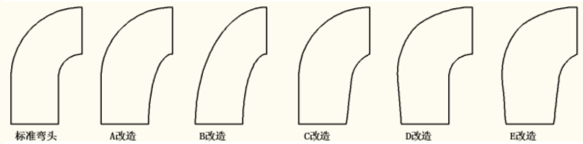
**弯头综合内外弧优化改造降阻效果对比表**
**Comparison table of drag reduction effect for comprehensive inner and outer arc elbow**

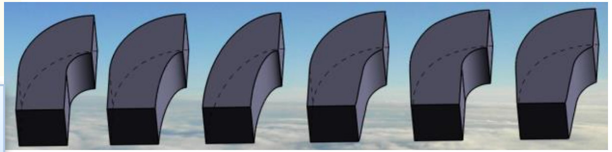
通过将内弧线、外弧线各自降阻效果较好的3种方案进行耦合，进行数值模拟。
Numerical simulation is carried out by coupling the three schemes of inner arc line and outer arc line with better drag reduction effects.

通过结果分析发现，降阻效果最好的弯头，并非来自最好的内外弧结合。
Through the analysis of the results, it is found that the elbow with the best drag reduction effect does not come from the best combination of inner and outer arcs.

# 弯头的扩展优化 Expansion optimization of elbow



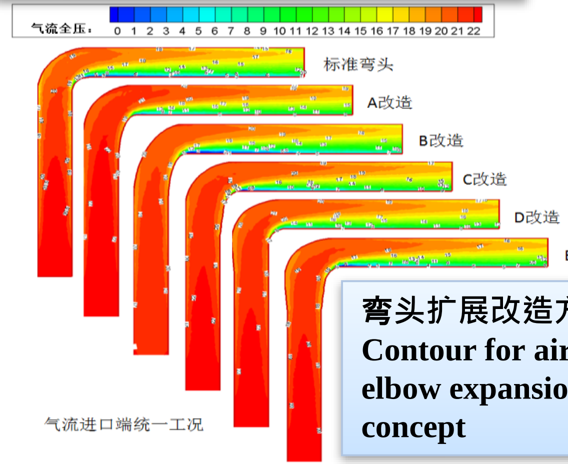



**扩展改造构想示意图**
**Schematic diagram of the expansion reconstruction concept**

**弯头扩展改造典型方案示意图**
**Schematic diagram of a typical scheme for expansion optimization of elbow**

扩展改造关键点：
The key points of expansion optimization:
1、扩展长度 Extended length
2、扩展方向 The Direction of expansion
3、**成本增加** Increasement in cost

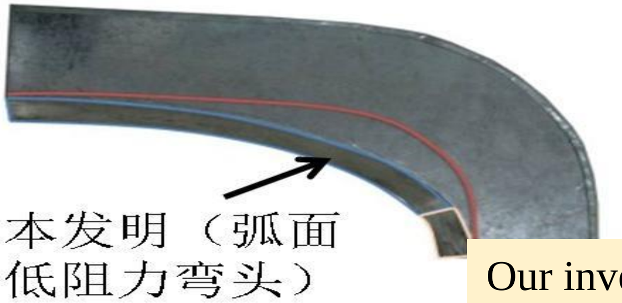



**弯头扩展改造方案的气流全压云图**
**Contour for airflow full pressure of elbow expansion reconstruction concept**

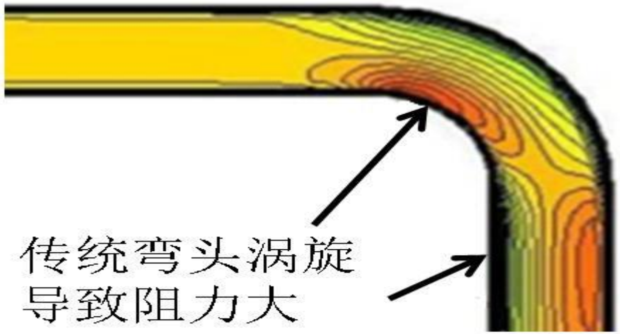
| | 气流速度 | 全压损失 | 相比弯头增减比率 |
|---|---|---|---|
| 弯头 | 6 | 8.15 | — |
| A | 6 | 7.74 | ↓7.43% |
| B | 6 | 7.96 | ↓3.33% |
| C | 6 | 7.73 | ↓7.49% |
| D | 6 | 7.75 | ↓7.22% |
| E | 6 | 7.32 | ↓15.01% |

**弯头扩展改造降阻效果对比表**
**Table of resistance reduction effect comparison for expansion optimization of elbow**

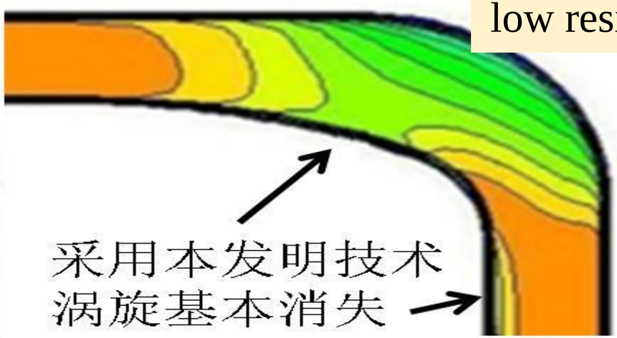

Traditional elbow( circular arc)




Our invention(curved low resistance elbow)

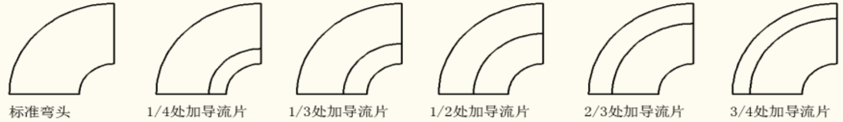



The vortex of traditional elbow leads to high resistance

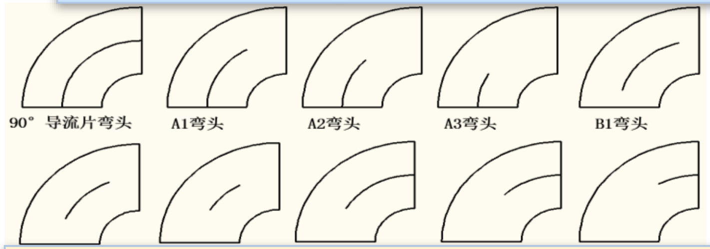



The vortex basically disappears by adopting the technology of our invention

# 弯头架设导流片优化 Optimization of guide vane for elbow erection




**导流片架设不同位置方案示意图**
**Schematic diagram of different positions of turning vane erection**




**不同长度导流片方案示意图**
**Schematic diagram of different length of turning vane**


**不同导流片片数方案示意图**
**Schematic diagram of different number of turning vane**

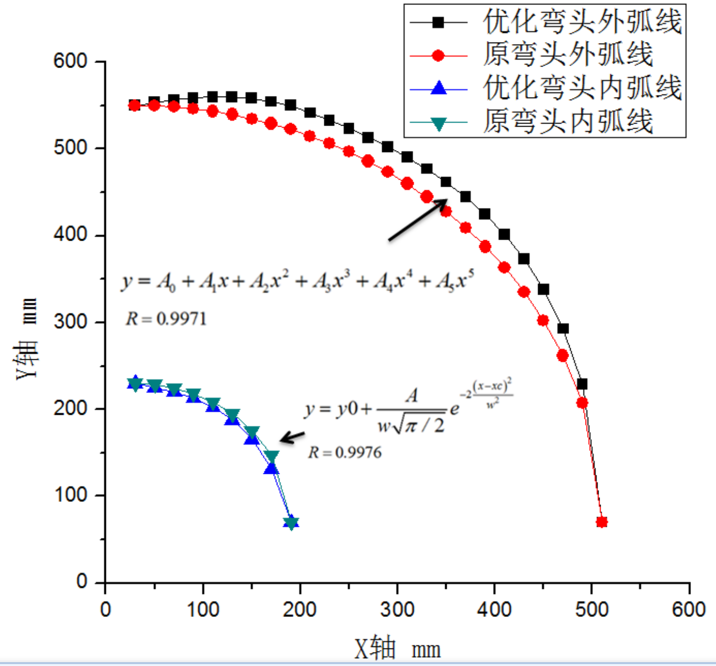
| | 气流速度 | 全压损失 | 相比弯头增减比率 |
|---|---|---|---|
| 弯头 | 6 | 8.15 | — |
| A | 6 | 8.14 | ↓1.05% |
| B | 6 | 7.94 | ↓3.70% |
| C | 6 | 7.92 | ↓4.18% |
| D | 6 | 8.04 | ↓1.90% |
| E | 6 | 8.07 | ↓1.44% |

| | 气流速度 | 全压损失 | 相比弯头增减比率 |
|---|---|---|---|
| 弯头 | 6 | 8.15 | — |
| A（2片） | 6 | 8.26 | ↑2.12% |
| B（3片） | 6 | 8.16 | ↑0.17% |
| C（4片） | 6 | 8.04 | ↓1.98% |
| D（5片 | | | |

**导流片架设不同位置、片数降阻效果对比表**
**Table of drag reduction effect comparison of different position and number**

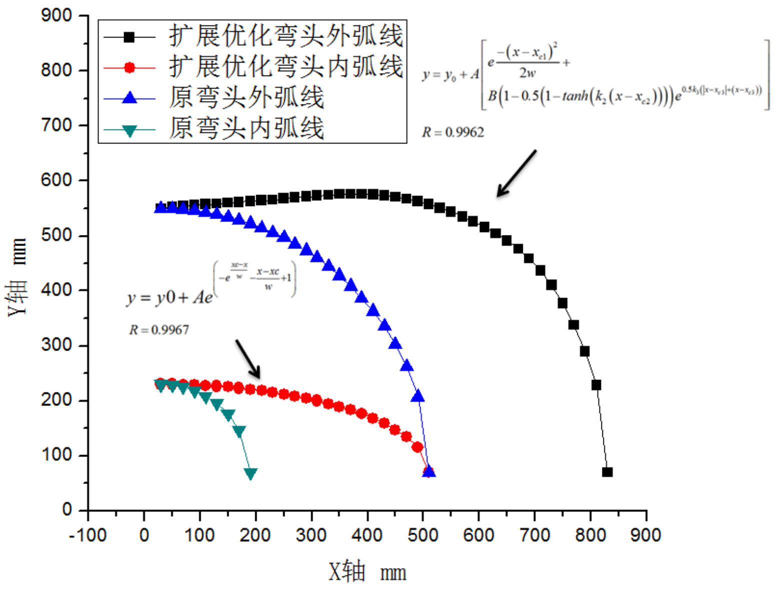
# 弯头优化改造弧线公式

## Curve formula of elbow optimization transformation




综合优化方案内、外弧线数据拟合对比图

**Diagram of data fitting comparison between the inner and outer arcs of the comprehensive optimization**




扩展优化方案内外弧线数据拟合对比图

**Diagram of data fitting comparison between inner and outer arcs of the expansion optimization**

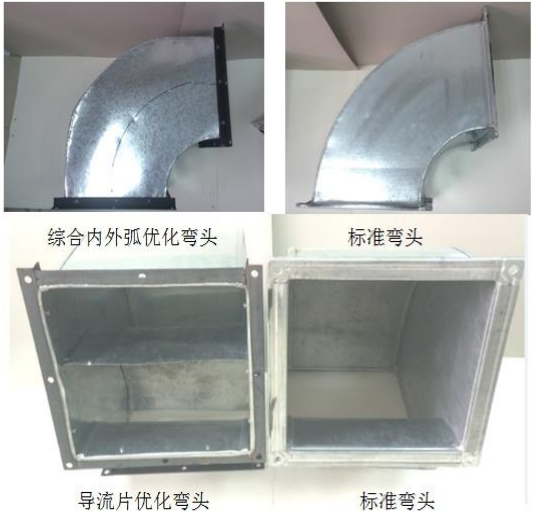
# 优化弯头降阻实验验证

## Optimized elbow drag reduction experiment verification

| 风管制作步骤<br>Manufacturing steps of air duct |
|---|
| **分解施工**蓝图 Disintegrate of construction blueprint |
| 风管展开下料 Unfolding and cutting of air duct |
| 风管组对铆接 Riveting of air duct assembly |

| 风管制作材料 Material of air duct |
|---|
| 1.2镀锌钢板 1.2 galvanized steel sheet |
| 1.0镀锌钢板 1.0 galvanized steel sheet |
| 0.75镀锌钢板 0.75 galvanized steel sheet |
| 0.6镀锌钢板 0.6 galvanized steel sheet |
| 0.5镀锌钢板 0.5 galvanized steel sheet |

**样品全尺寸**
**Full size of sample**



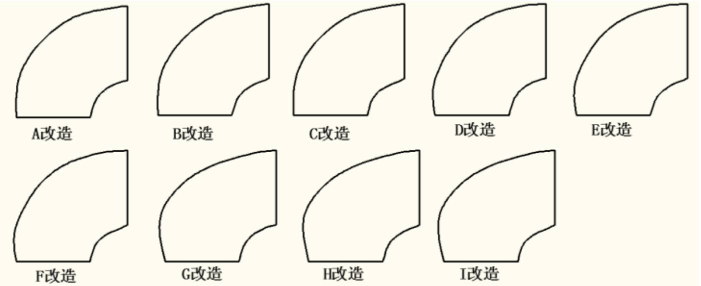

**成本综合分析**
**Comprehensive cost analysis**

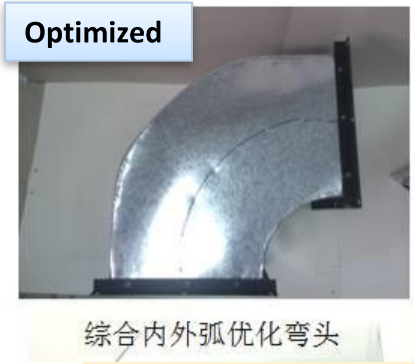
**加工材料费**
**Processing material fee**

| 项目 Project |
|---|
| 风管钢板成本费<br>Cost of duct steel plate |
| **手工及机械费**<br>Labor and machinery cost |
| |

| **安装步骤** Installation procedure |
|---|
| **吊架制作** Hanger fabrication |
| **吊架安装** Hanger installation |
| 风管吊装 Hoisting of air duct |
| **机房**风管安装 Air duct installation |
| 连接设备 Devices connection |

# 弯头最佳形状 Best shape of elbow



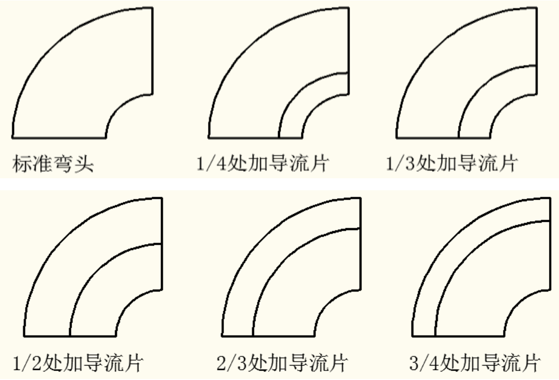





**弯头最佳形状降阻效果**
Drag reduction effect of the optimized shape for elbows

| 弯头<br>Elbow | 全压损失<br>Total pressure loss | 相比标准弯头增减比率<br>Increase / decrease ratio compared with standard elbow |
|---|---|---|
| 传统 | 8.15 | — |
| A | 8.00 | ↓2.48% |
| B | 7.91 | ↓4.29% |
| C | 8.12 | ↓0.46% |
| D | 7.64 | ↓9.21% |
| E | 7.93 | ↓3.40% |
| F | 7.86 | ↓5.18% |
| G | 8.02 | ↓2.35% |
| H | 8.03 | ↓2.03% |
| I | 7.89 | ↓4.62% |

# 弯头最佳导流叶片位置 Best turning vane position for elbow

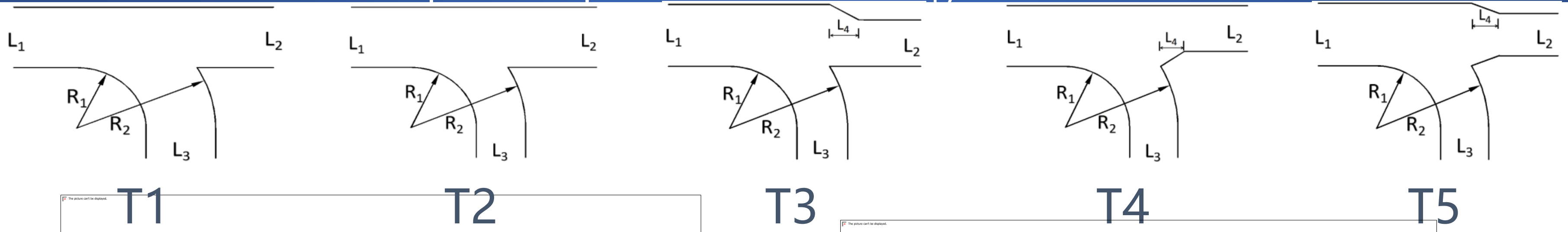




## 导流叶片减阻
## Turning vane drag reduction

| | 全压损失<br>Total pressure loss | 相比标准弯头<br>增减比率<br>Increase / decrease ratio compared with standard elbow |
|---|---|---|
| 标准弯头 | 8.15 | — |
| A | 8.14 | ↓1.05% |
| B | 7.94 | ↓3.70% |
| C | 7.92 | ↓4.18% |
| D | 8.04 | ↓1.90% |
| E | 8.07 | ↓1.44% |

# 三通内导流叶片最佳位置
## Optimized position of the turning vanes in the tee

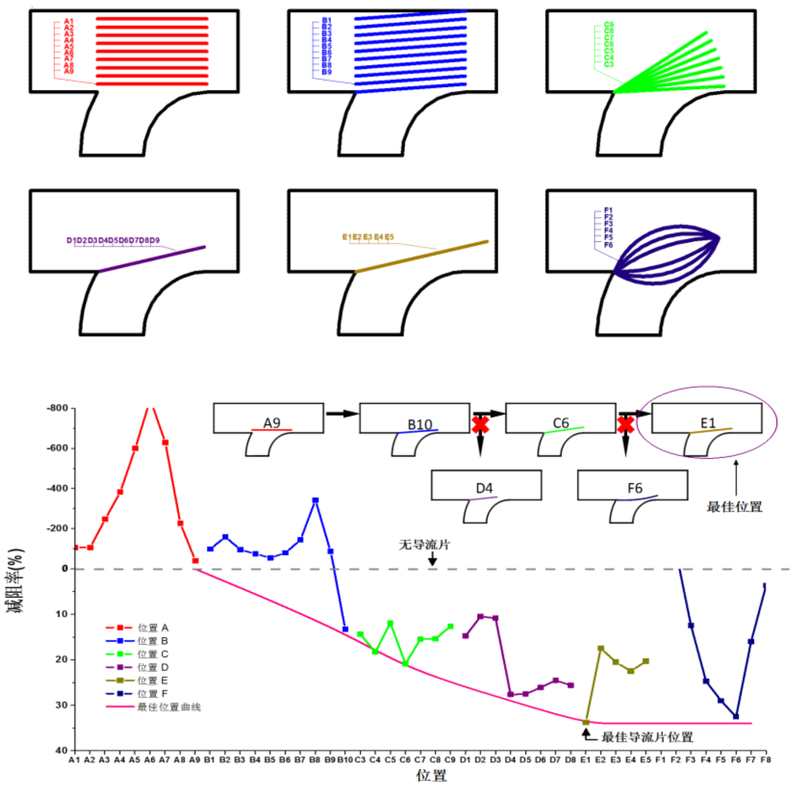


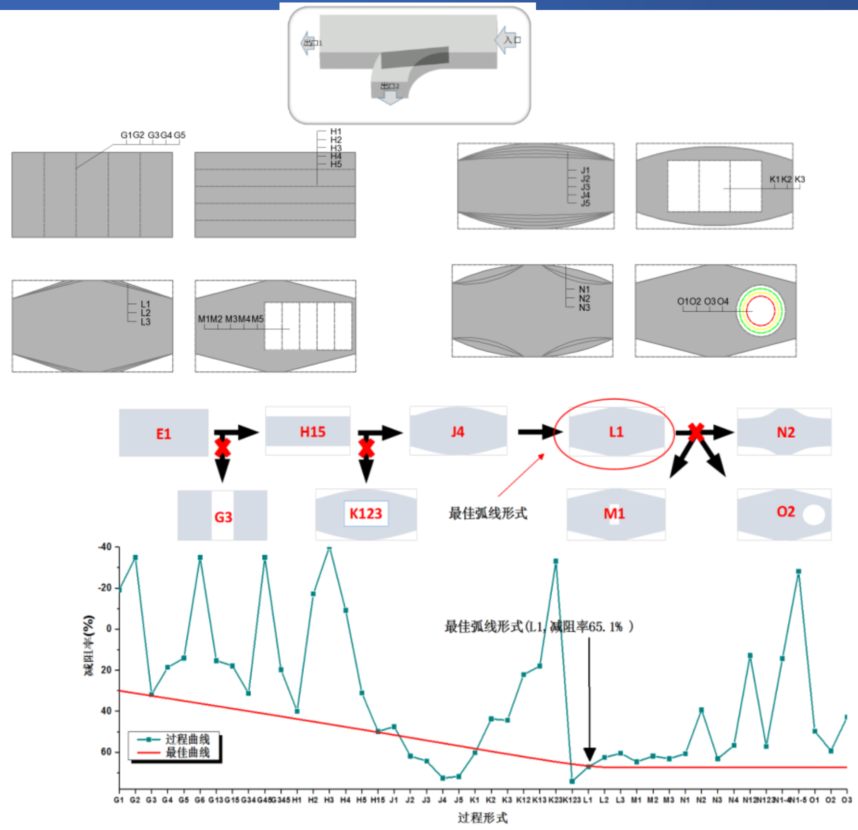

（a）单一流速比
Single flow rate ratio

（b） 变流速比
Variable flow rate ratio

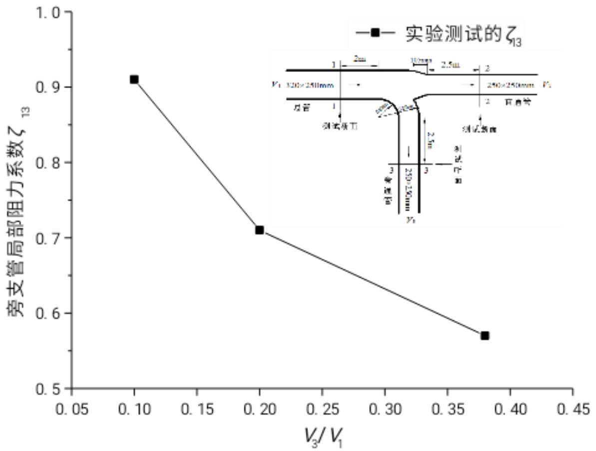
**五种**类型三通的最佳导流片位置对比
Comparison of the best turning vane positions of five types of tee

# 三通内导流叶片形状 Shapes of the turning vane in Tee



# 三通减阻技术研发
## Tee drag reduction technology research and development




气流在三通下游20de，流体才逐渐恢复稳定。
When the air flow is 20 de downstream of the tee, the fluid gradually returns to stability.

分流T型三通随着旁支管与总管速度比$V_3/V_1$的增加，旁支管局部阻力系数$\zeta_{13}$逐渐降低。
With the increase of the velocity ratio $V_3/V_1$ of the branch duct to the main duct, the local resistance coefficient $\zeta_{13}$ of the branch duct gradually decreases.

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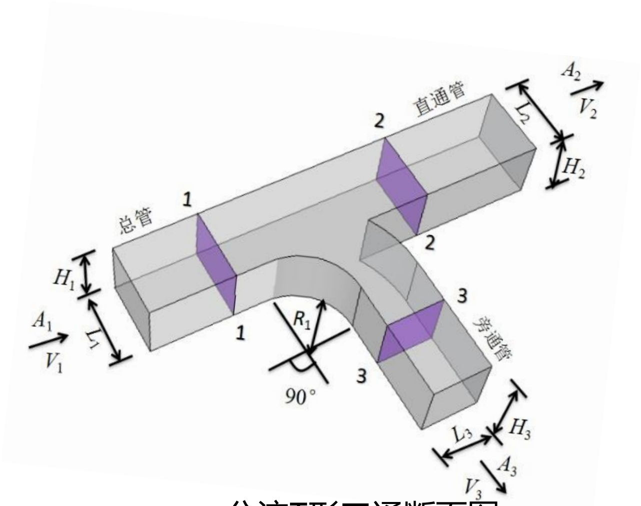
## Tee drag reduction technology research and development




分流T形三通断面图

Sectional view of shunt T-shaped tee

在三通直管上游，管道中心线速度沿管道流动方向增加；在靠近三通处，靠近三通侧的速度大于远离三通侧的速度；三通下游，管道中心线速度沿直管流动方向逐渐增高，靠近三通侧的速度先增大，之后逐渐减少，并且大于远离三通侧速度，流体发生偏移，额外附加阻力。

In the upstream of a straight tee, the centerline velocity of the duct increases along the flow direction of the duct; near the tee, the velocity on the side close to the tee is greater than the velocity on the side away from the tee; downstream of the tee, the centerline velocity of the duct follows the flow direction of the straight duct gradually incline, the speed near the tee side increases first, and then gradually decreases, and is greater than the speed far away from the tee side, the fluid shifts, and additional resistance is added.

# 分流T形三通速度场、压力场数值模拟

## Numerical simulation of velocity field and pressure field of split-flow T-shaped tee

$V_3/V_1$=0.1时，高度中心面速度图

Contour of velocity at center plane height when $V_3/V_1$=0.1

$V_3/V_1$=0.38时，高度中心面速度图

Contour of velocity at center plane height when $V_3/V_1$=0.38

$V_3/V_1$=0.1时，高度中心面压力图

Contour of pressure at center plane height when $V_3/V_1$=0.1

$V_3/V_1$=0.38时，高度中心面压力图

Contour of pressure at center plane height when $V_3/V_1$=0.38

流体经三通分流到旁支管，在三通来流方向外侧形成明显的高压区，三通来流方向内侧形成明显的低压区。当旁支管与总管速度比$V_3/V_1$增大时，直通管下游靠近三通侧压力大于远离三通侧的压力，压力发生偏移，造成了局部损失。

The fluid is diverted to the branch duct through the tee, forming a clear high pressure area outside the tee flow direction, and forming a clear low pressure area inside the tee flow direction. When the speed ratio $V_3/V_1$ of the branch duct to the main duct increases, the pressure on the downstream side of the straight duct near the tee is greater than the pressure on the side far away from the tee, and the pressure shifts, causing local resistance losses.

# 分流T形三通速度场、压力场数值模拟
## Numerical simulation of velocity field and pressure field of split-flow T-shape tee

$V_3/V_1$=0.1时，风管高度方向中心面沿直管段速度场

Velocity of the center plane of the duct height direction along the straight section when $V_3/V_1$=0.1,

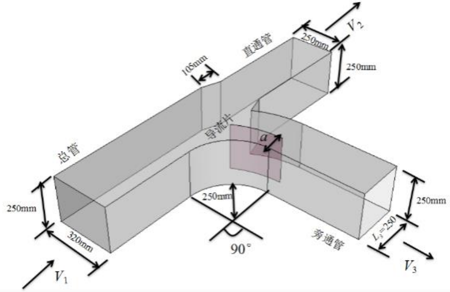
$V_3/V_1$=0.38时，风管高度方向中心面沿直管段速度场

Velocity field of the center plane along the straight duct section in the height direction of the air duct when $V_3/V_1$=0.38,

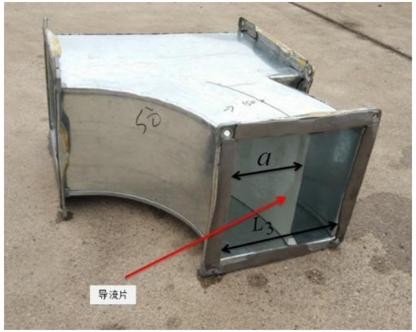
在三通上游，中心线速度大于中心线两侧的速度，靠近三通处，三通内侧的直管段速度大于远离三通侧的速度，在三通下游，当旁支管与总管速度比$V_3/V_1$增大时，直通管偏移更明显。

At the upstream of the tee, the centerline speed is greater than the speed on both sides of the centerline. Near the tee, the speed of the straight duct section inside the tee is greater than the speed far away from the tee. At the downstream of the tee, when the speed ratio of the branch duct to the main duct $V_3/V_1$ increases, the straight-through tube offset will act more obvious.

# 导流片减阻方法 Turning vane drag reduction method




数值模拟 Numerical simulation




实验验证 Experimental verification

- 五种不同三通及变径方式

Five different tee and reducing methods

1、直通管不变径、旁支管不变径

The straight-through pipe and the by-pass pipe do not reducing

2、直通管不变径、旁支管变径

The straight-through pipe does not change its diameter, while the by-pass pipe reducing

3、直通管变径（单面偏上对齐）、旁支管变径

Both straight-through pipe (alignment on one side upside) and by-pass pipe reducing

4、直通管变径（单面偏下对齐）、旁支管变径

Both straight-through pipe (alignment on the lower side of one side) and by-pass pipe reducing

5、直通管变径（双面偏）、旁支管变径

Both straight-through pipe (double-sided deviation) and by-pass pipe reduction

# 导流片减阻方法 Turning vane drag reduction method

当$V_3/V_1$=0.1时，推荐的最佳导流片在$a/L_3$=0.3处。

When $V_3/V_1$=0.1, the recommended turning vane is at $a/L_3$ =0.3.

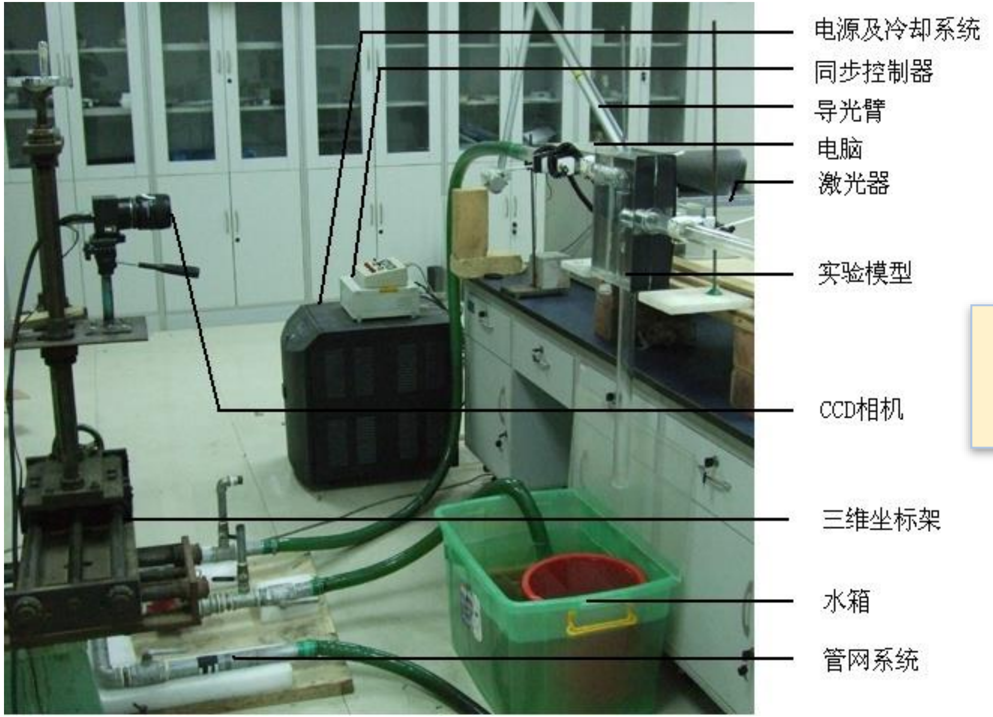
当$V_3/V_1$=0.2时，推荐的最佳导流片在$a/L_3$=0.4处。

When $V_3/V_1$=0.2, the recommended turning vane is at $a/L_3$ =0.4.

当$V_3/V_1$=0.3时，推荐的最佳导流片在$a/L_3$=0.6处，但三通下对齐方式没有减阻效果。

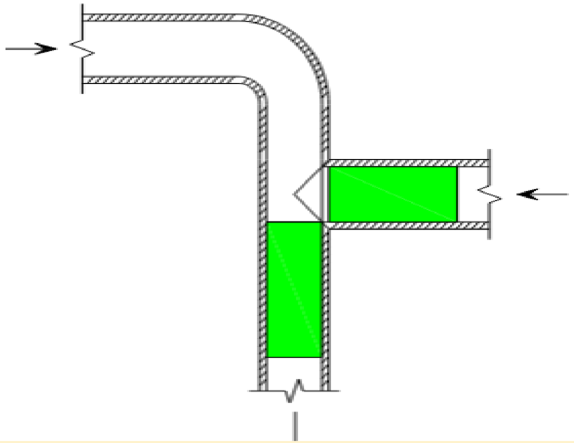
When $V_3/V_1$=0.3, the recommended turning vane is at $a/L_3$ =0.6.

# 弯头耦合三通减阻 Elbow coupling tee drag reduction




2DPIV实验
2DPIV experiment

# PIV实验 PIV experiment



绿色为拍摄区域

**Green indicates the shooting area**

# PIV实验与CFD对比 Comparison of PIV experiment and CFD

Velocity field of CFD simulation without drag reduction

Velocity field of PIV experiment without drag reduction

Velocity field of CFD simulation with wedge drag reducer

Velocity field of PIV experiment with wedge drag reducer

**区域II**
**$V_{m1}$=1.07,**
**$V_{m2}$=0.94**
**CFD及PIV**

**Area II**
**CFD and PIV**
**of $V_{m1}$=1.07,**
**$V_{m2}$=0.94**

**区域I七种流速d的CFD及PIV**

**Area I CFD and PIV of seven flow velocities**

**区域I$V_{m1}$=0 m/s，$V_{m2}$=1.57 m/s CFD模拟及PIV实验速度场**

**区域I$V_{m1}$=0.36 m/s，$V_{m2}$=1.49 m/s CFD模拟及PIV实验速度场**

**区域I$V_{m1}$=0.68m/s，$V_{m2}$=1.24m/s CFD模拟及PIV实验速度场**

**区域I$V_{m1}$=1.07 m/s，$V_{m2}$=0.94 m/s CFD模拟及PIV实验速度场**

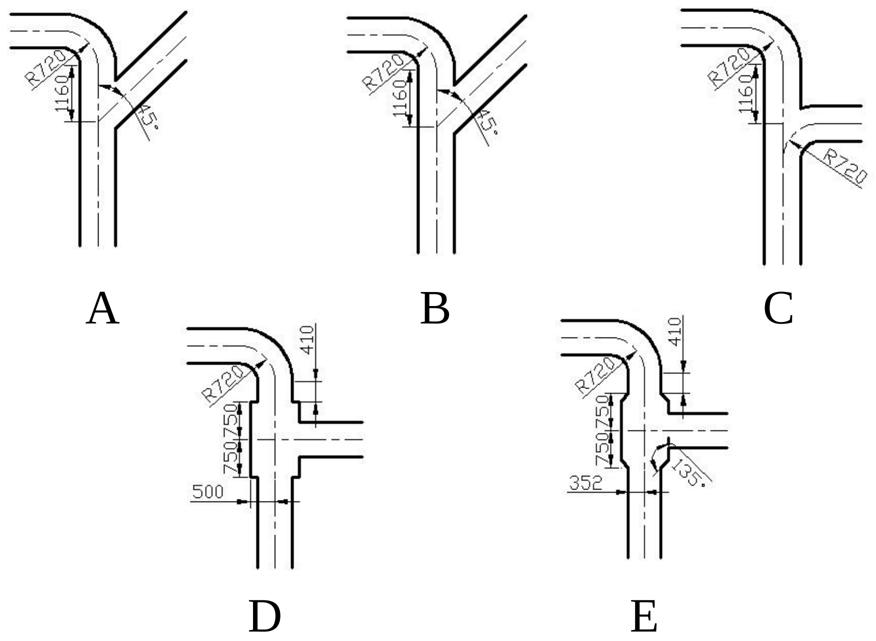
**区域I$V_{m1}$=1.23 m/s，$V_{m2}$=0.65 m/s CFD模拟及PIV实验速度场**

**区域I$V_{m1}$=1.44 m/s，$V_{m2}$=0.36 m/s CFD模拟及PIV实验速度场**

**区域I$V_{m1}$=1.73 m/s，$V_{m2}$=0 m/s CFD模拟及PIV实验速度场**

# 支管连接方式对弯头与三通耦合阻力影响

## The influence of branch pipe connection mode on the resistance of elbow and tee coupling




几种连接方式示意图
Schematic diagram of several connection methods

**改**变支管与干管的连接方式，**支管内流**动方向与干管尽量接近、**减小合流和分流旋**涡区范围，**减小局部阻力**。

Change the connection between the branch pipe and the main pipe, make the flow direction in the branch pipe as close as possible to the main one, reduce the confluence and diversion vortex area, as well as the local resistance.

连接时采用混合箱。**方案C在各种情况下最优**，**方案B**优于A，**方案D、E没有达到**预**期目的**。

Use a mixing box when connecting. Scheme C is optimal in various situations, scheme B is better than scheme A, schemes D and E do not achieve the expected goals.

# 弯头与三通近距耦合减阻
# Elbow and tee close coupling drag reduction

减阻件Ⅰ：减阻件管道径向距离为管道直径1/8

Drag reducer I: The radial distance of the drag reducer is 1/8 of the pipe diameter

- 减阻件Ⅱ：减阻件管道径向距离为管道直径1/4

Drag reducer Ⅱ : The radial distance of the drag reducer is 1/4 of the pipe diameter

- 减阻件Ⅲ：减阻件管道径向距离为管道直径3/8。

Drag reducer III : The radial distance of the drag reducer is 3/8 of the pipe diameter

**减阻件示意图 Schematic diagram of drag reducer**

# 弯头与三通近距耦合减阻
# Elbow and tee close coupling drag reduction

- **减阻件** Drag reducer

对于HVAC**范**围，减阻件的最大管道径向距离不宜超过管道直径1/4。

For HVAC, the maximum pipe radial distance of the drag reducer should not exceed 1/4 of the pipe diameter.

The picture can't be displayed.

**合流局部阻力系数$\zeta_{13}$减阻件减阻效果**对比

**Comparison of drag reduction effect of confluence local resistance coefficient $\zeta_{13}$ drag reducer**

**合流局部阻力系数$\zeta_{23}$减阻件减阻效果**对比

**Comparison of drag reduction effect of confluence local resistance coefficient $\zeta_{23}$ drag reducer**

# 弯头与三通近距耦合减阻

# Elbow and tee close coupling drag reduction

## ➢ 优化减阻件外形结构 Optimize the shape and structure of the drag reducer

- 对于合流工况局部阻力系数$\zeta_{13}$，在流速比$V_{m1}/V_{m3}<1$的工况下，减阻件Ⅷ的减阻效果显著，减阻率处于17.18%～47.61%之间;

For the coefficient of local resistance $\zeta_{13}$ under the confluence condition, and the flow velocity ratio $V_{m1}/V_{m3}<1$, the drag reduction effect of drag reducer VIII is significant, and the drag reduction rate is between 17.18% and 47.61%;

- 对于合流工况局部阻力系数$\zeta_{23}$，综合考虑各减阻件在不同工况下的减阻效果，减阻件X的减阻效果较优，减阻率达～41.30%;

For the coefficient of local resistance $\zeta_{23}$ under the confluence condition, considering the drag reduction effect of each drag reducer under different working conditions comprehensively, the drag reduction effect of drag reducer X is better, and the drag reduction rate is 41.30%;

# 弯头与三通近距耦合减阻
# Elbow and tee close coupling resistance reduction

## ➢ 优化减阻件外形结构 Optimize the shape and structure of the resistance reducer

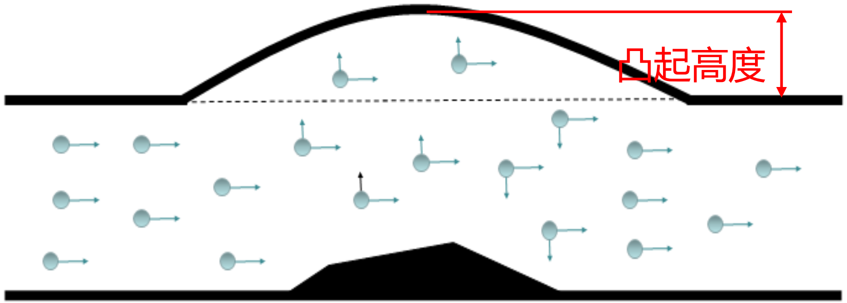
- 对于分流工况局部阻力系数$\zeta_{31}$，减阻件VI在流速比$V_{m1}/V_{m3}<0.8$的条件下减阻率处于12.73%～23.89%之间;

For the coefficient of local resistance $\zeta_{31}$ under the shunt condition, the drag reduction rate of the drag reducer VI is between 12.73% and 23.89% when the flow velocity ratio $V_{m1}/V_{m3}<0.8$;

- 对于分流工况局部阻力系数ζ32，在流速比Vm1/Vm3>0.5的工况下减阻件减阻效果不明显，在流速比Vm1/Vm3<0.5的工况下，减阻件X有较好的减阻表现，减阻率处于10.21%～17.90%之间。

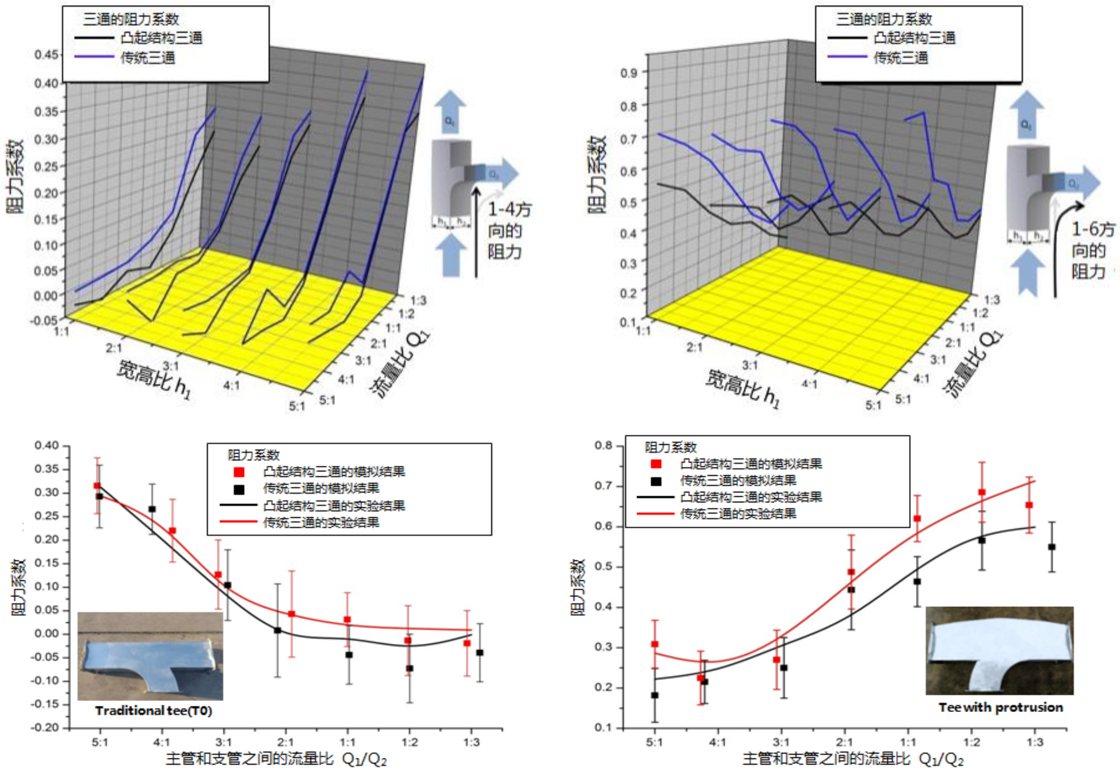
For the coefficient of local resistance $\zeta_{32}$ under the shunt condition, and the flow velocity ratio $V_{m1}/V_{m3}>0.5$, the drag reduction effect of the drag reducer is not obvious. When the flow velocity ratio $V_{m1}/V_{m3}<0.5$, the drag reducer X has a better performance, and the drag reduction rate is 10.21%～17.90%.

# 三通优化 Optimization of tee

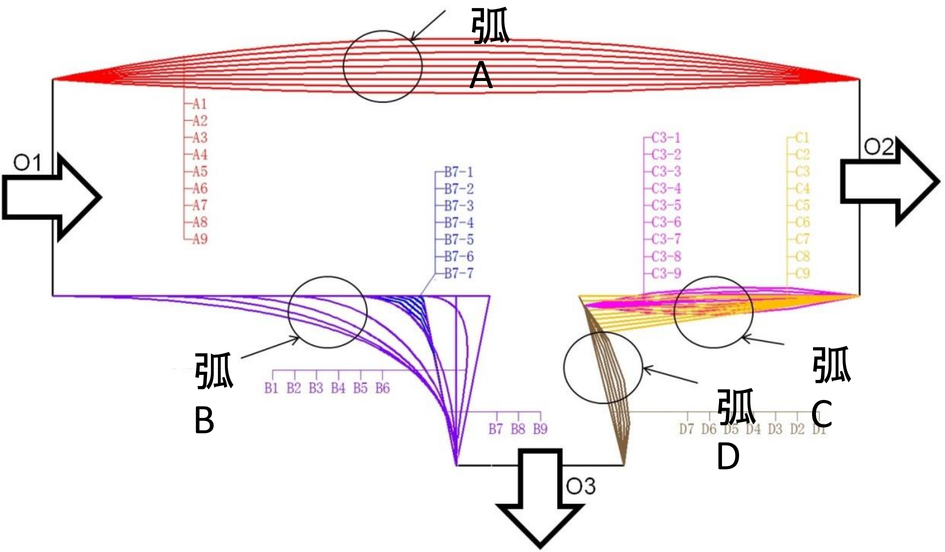

凸起结构减阻机理 Drag reduction mechanism of convex structure

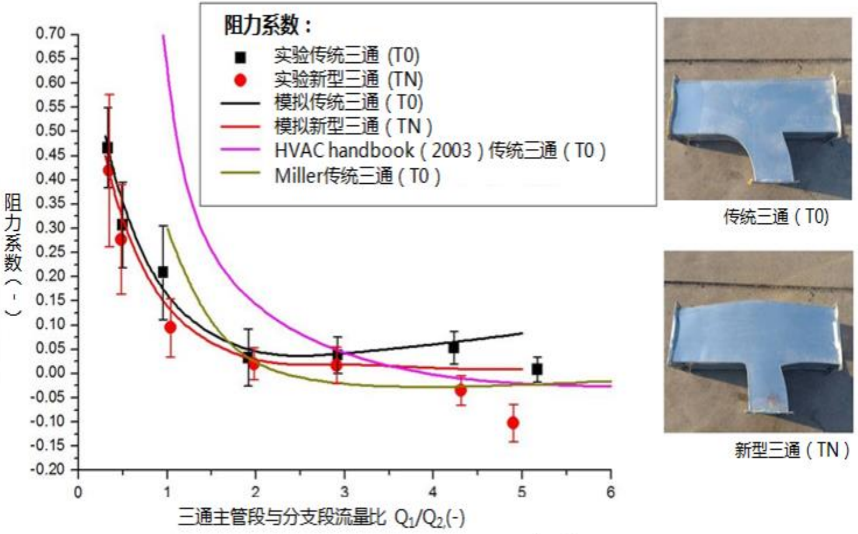
# 三通优化 Optimization of tee




Flow ratio between main pipe and branch pipe

# 三通优化 Optimization of tee




Flow ratio between main pipe and branch pipe of tee

# 报告内容 Content

Drag reduction of HVAC piping distribution system

通风空调输配系统减阻

# 风管宽度>1000mm三通优化结构

## Optimized structure of tee for duct width greater than 1000mm

| 速度比$V_3/V_1$ | | | 0.25 | | 0.3 | | 1/3 | | 0.4 | |
|---|---|---|---|---|---|---|---|---|---|---|
| 总管 | 直通管 | 旁通管 | 前列：推荐导流片位置　后列：减阻率 | | | | | | | |
| 320×250 | 320×250 | 320×250 | 0.5 | 19.3% | 0.5 | 9.7% | | | | |
| 400×200 | 400×200 | 400×200 | 0.5 | 15.0% | 0.6 | 9.9% | 0.6 | 4.8% | | |
| 500×200 | 500×200 | 500×200 | 0.5 | 10.4% | 0.5 | 7.6% | 0.6 | 3.5% | | |
| 500×250 | 500×250 | 500×250 | 0.5 | 13.1% | 0.5 | 9.7% | 0.6 | 7.4% | | |
| 500×320 | 500×320 | 500×320 | 0.5 | 28.5% | 0.5 | 24.9% | 0.7 | 23.6% | 0.7 | 21.6% |
| 500×400 | 500×400 | 500×400 | 0.5 | 11.6% | 0.6 | 11.9% | 0.6 | 8.3% | | |
| 500×500 | 500×500 | 500×500 | 0.5 | 21.9% | 0.5 | 10.0% | 0.6 | 10.6% | 0.7 | 9.3% |
| 630×250 | 630×250 | 630×250 | 0.5 | 8.9% | 0.6 | 7.1% | 0.6 | 4.2% | | |
| 630×320 | 630×320 | 630×320 | 0.5 | 9.3% | 0.6 | 7.1% | 0.6 | 9.8% | | |
| 630×400 | 630×400 | 630×400 | 0.5 | 10.8% | 0.6 | 8.2% | 0.6 | 10.8% | 0.7 | 4.5% |
| 630×500 | 630×500 | 630×500 | 0.5 | 16.7% | 0.6 | 17.7% | 0.6 | 16.4% | | |
| 630×630 | 630×630 | 630×630 | 0.5 | 11.2% | 0.5 | 4.0% | | | | |
| 800×320 | 800×320 | 800×320 | 0.5 | 9.5% | 0.6 | 8.1% | 0.6 | 5.7% | | |
| 800×400 | 800×400 | 800×400 | 0.5 | 12.0% | 0.6 | 7.5% | 0.6 | 7.2% | | |
| 800×500 | 800×500 | 800×500 | 0.5 | 8.4% | 0.6 | 6.8% | 0.6 | 9.7% | 0.7 | 7.0% |

# 风管宽度>1000mm三通优化结构

Optimized structure of tee for duct width greater than 1000mm

| 速度比$V_3/V_1$ | | | 0.25 | | 0.3 | | 1/3 | | 0.4 | |
|---|---|---|---|---|---|---|---|---|---|---|
| 总管 | 直通管 | 旁通管 | 前列：推荐导流片位置 后列：减阻率 | | | | | | | |
| 1250×400 | 1250×400 | 1250×400 | 0.5 | 15.2% | 0.6 | 12.6% | 0.6 | 5.2% | | |
| | | | 0.5,0.6 | 17.0% | 0.6,0.8 | 15.1% | 0.6,0.8 | 10.7% | | |
| 1250×500 | 1250×500 | 1250×500 | 0.5 | 11.9% | 0.6 | 12.3% | 0.6 | 12.7% | 0.7 | 7.0% |
| | | | 0.5,0.8 | 12.9% | 0.6,0.8 | 11.5% | 0.6,0.8 | 14.1% | | |
| 1250×630 | 1250×630 | 1250×630 | 0.5 | 12.4% | 0.5 | 9.6% | 0.6 | 10.6% | | |
| | | | 0.5,0.8, | 14.2% | 0.6,0.7 | 9.6% | 0.6,0.8 | 13.1% | | |
| 1250×800 | 1250×800 | 1250×800 | 0.5 | 17.8% | 0.6 | 10.7% | 0.6 | 11.4% | 0.7 | 10.2% |
| | | | 0.5,0.8 | 18.9% | 0.6,0.9 | 13.0% | 0.6,0.8 | 13.2% | | |
| 1250×1000 | 1250×1000 | 1250×1000 | 0.5 | 22.4% | 0.6 | 17.1% | 0.6 | 17.8% | 0.7 | 13.3% |
| | | | 0.5,0.8 | 23.7% | 0.6,0.8 | 20.7% | 0.6,0.8 | 19.3% | | |

# 风管宽度>1000mm三通优化结构

Optimized structure of tee for duct width greater than 1000mm

续表：

| 速度比$V_3/V_1$ | | | 0.25 | | 0.3 | | 0.35 | | 0.4 | |
|---|---|---|---|---|---|---|---|---|---|---|
| 总管 | 直通管 | 旁通管 | 前列：推荐导流片位置 后列：减阻率 | | | | | | | |
| 1600×630 | 1600×630 | 1600×630 | 0.5 | 17.0% | 0.6 | 15.9% | 0.6 | 16.1% | 0.7 | 7.4% |
| | | | 0.5,0.8 | 19.6% | 0.6,0.7 | 16.3% | 0.6,0.8 | 16.7% | | |
| 1600×800 | 1600×800 | 1600×800 | 0.5 | 28.1% | 0.6 | 22.8% | 0.6 | 22.1% | 0.7 | 26.2% |
| | | | 0.5,0.9 | 29.5% | 0.6,0.8 | 28.9% | 0.6,0.8 | 23.90% | 0.6,0.7 | 20.4% |
| 1600×1000 | 1600×1000 | 1600×1000 | 0.5 | 24.4% | 0.6 | 19.3% | 0.6 | 24.9% | 0.7 | 14.2% |
| | | | 0.5,0.9 | 28.1% | 0.6,0.7 | 23.8% | 0.6,0.8 | 25.1% | | |
| 1600×1250 | 1600×1250 | 1600×1250 | 0.5 | 31.4% | 0.6 | 21.0% | 0.6 | 26.7% | 0.7 | 21.2% |
| | | | 0.5,0.9 | 35.4% | 0.6,0.8 | 23.6% | 0.6,0.8 | 28.1% | | |
| 2000×800 | 2000×800 | 2000×800 | 0.5 | 15.6% | 0.5 | 10.1% | 0.6 | 14.1% | 0.7 | 9.2% |
| | | | 0.5,0.6 | 15.2% | 0.6,0.8 | 13.9% | 0.6,0.8 | 14.5% | | |
| 2000×1000 | 2000×1000 | 2000×1000 | 0.5 | 17.3% | 0.6 | 14.1% | 0.6 | 19.3% | 0.7 | 11.6% |
| | | | 0.5,0.8 | 19.6% | 0.6,0.8 | 16.0% | 0.6,0.8 | 21.1% | | |
| 2000×1250 | 2000×1250 | 2000×1250 | 0.5 | 14.6% | 0.5 | 14.6% | 0.6 | 18.7% | 0.7 | 12.5% |
| | | | | | | | | | | |

# 三通变径优化结构 Optimized structure of reducing tee

| 速度比$V_3/V_1$ | | | | 0.1 | | 0.2 | | 0.3 | | 0.4 | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 总管 | 直通管 | | 旁支管 | 前列：推荐导流片位置　后列：减阻率 | | | | | | | |
| 320×200 | 320×200 | | 200×200 | 0.3 | 18.1% | 0.4 | 19.5% | 0.6 | 8.3% | | |
| | 250×200 | (下对齐) | 200×200 | 0.3 | 17.7% | 0.4 | 17.7% | 0.5 | 10.3% | | |
| | 250×200 | (双面偏) | 200×200 | 0.3 | 18.1% | 0.4 | 18.7% | 0.7 | 4.2% | | |
| | 250×200 | (上对齐) | 200×200 | 0.3 | 14.4% | 0.5 | 12.5% | | | | |
| 400×200 | 400×200 | | 200×200 | 0.3 | 15.8% | 0.4 | 17.0% | 0.6 | 11.0% | | |
| | 400×200 | | 400×200 | 0.3 | 32.6% | 0.4 | 21.1% | 0.6 | 9.9% | | |
| | 320×200 | (下对齐) | 200×200 | 0.4 | 15.0% | 0.4 | 18.4% | 0.6 | 9.6% | | |
| | 320×200 | (双面偏) | 200×200 | 0.3 | 17.3% | 0.4 | 19.0% | 0.7 | 4.6% | | |
| | 320×200 | (上对齐) | 200×200 | 0.3 | 16.5% | 0.4 | 15.1% | | | | |

# 关键构件优化 Optimization of key components

1. T型分流整流三通

T-shaped shunt rectifier tee

2. 十字型分流整流四通

Cross shunt rectifier cross

3. 矩形风管Y形对称燕尾分流整流三通

Rectangular duct Y-shaped symmetrical dovetail split rectifier tee

4. 矩形断面Z型整流弯管

Z-shaped rectifier elbow with rectangular section

5. 矩形风管分隔式合流整流三通

Rectangular duct partitioned combined rectifier tee

6. ∏型180°整流弯管

∏ - shaped 180 ° rectifier elbow

7. 90°整流矩形弯管

90° rectangular rectifier elbow

8. 低阻力方形渐扩变径构件

Low resistance square expansion variable diameter component

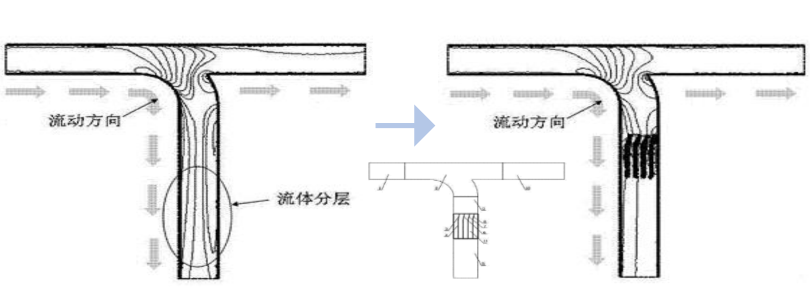
9. 低阻力方形弯头

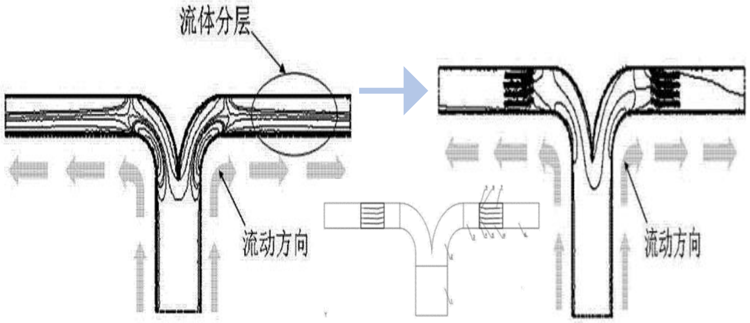
Low resistance square elbow

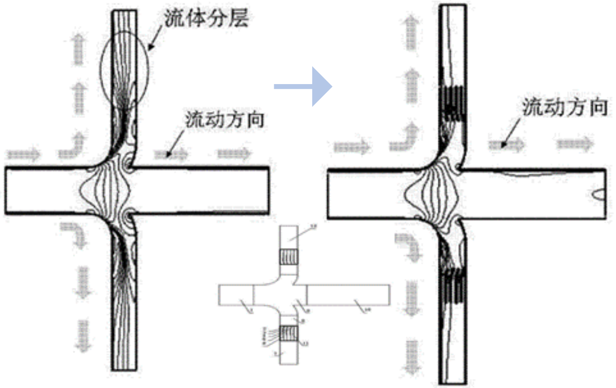
10. 低阻力方形裤衩三通

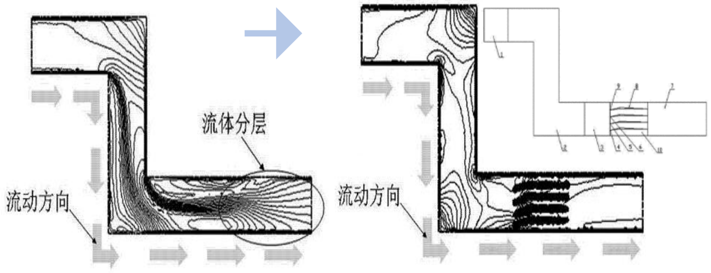
Low resistance square underpants-shaped tee

# 关键构件优化 Optimization of key components

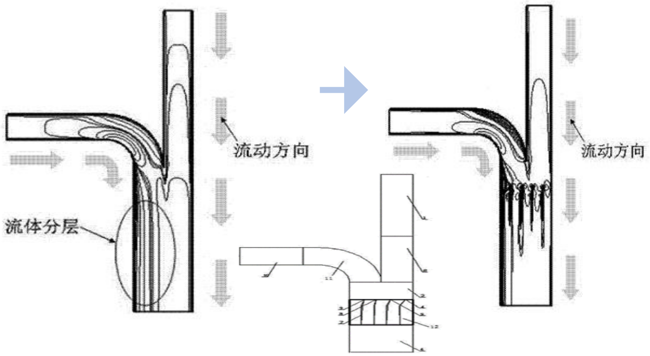


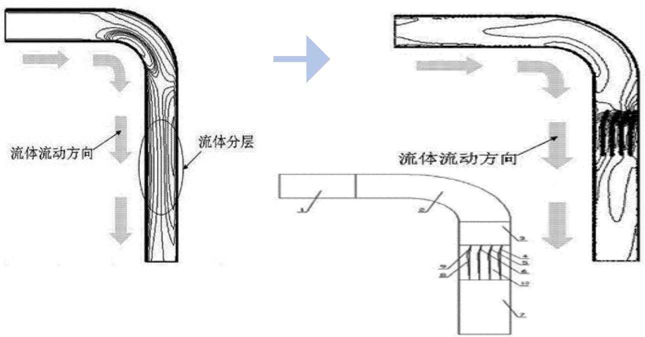



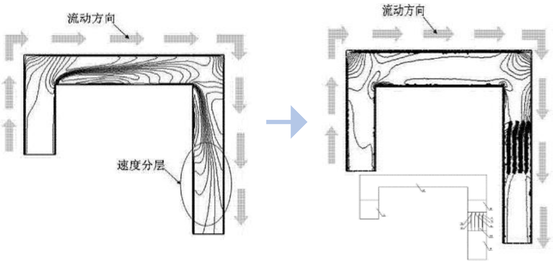



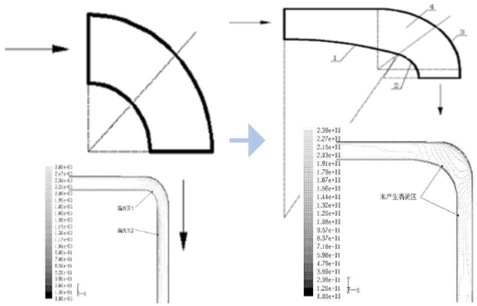



# 关键构件优化 Optimization of key components

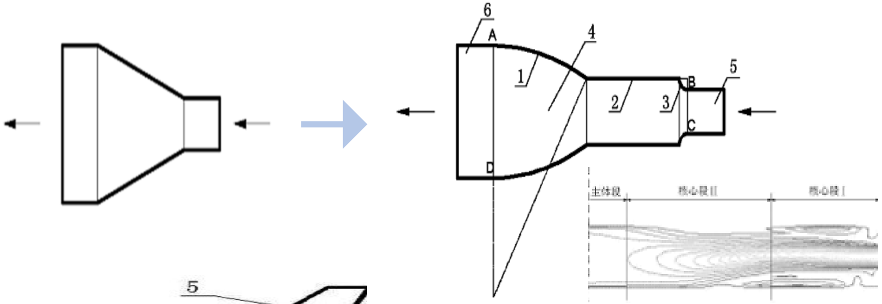


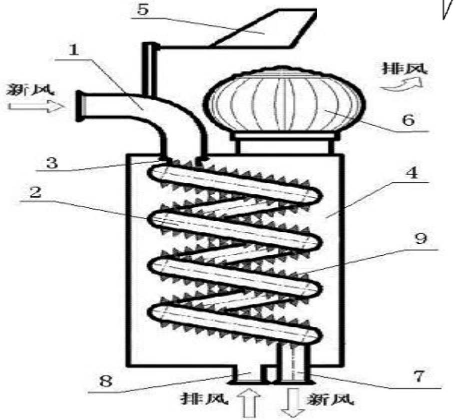



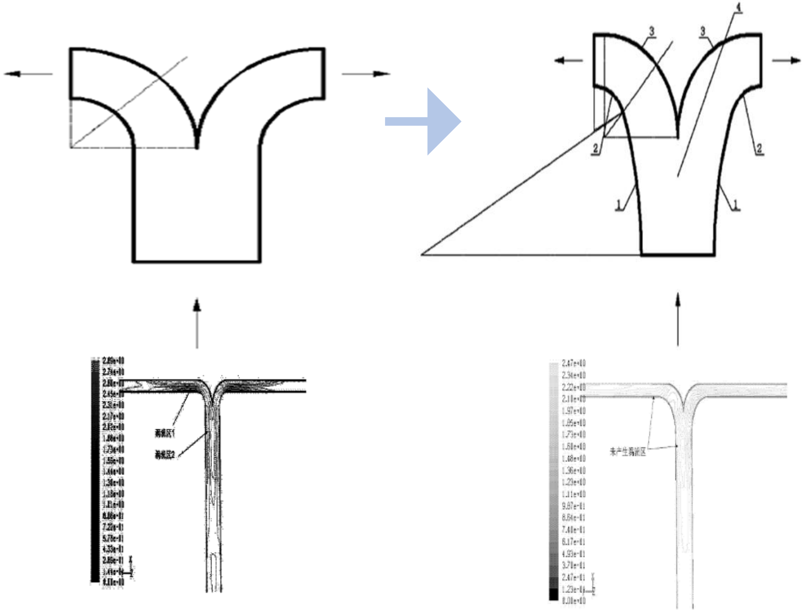



# 关键构件优化 Optimization of key components



# 关键构件优化（照片）Optimization of key components (photo)

# 报告内容 Content

Drag reduction of HVAC piping distribution system

通风空调输配系统减阻

# 小结 Summary

- 通风空调输配系统的减阻作为建筑能耗十分重要的一部分，需要充分重视。
  As a part occupied a large proportion of building energy consumption, the drag reduction of the HVAC piping distribution system should be paid more attention.

- 通过对通风空调输配系统关键构件各种优化方式的探究与验证，使关键构件局部阻力减少10%以上。
  Through the experiment and verification of drag reduction methods for key components of the HVAC piping system, the local resistance loss of the key components can be reduced by more than 10%.

- 目前的优化方式针对通风空调输配系统管道，宜对通风空调输配系统中水系统的减阻问题深入探索。
  The current optimization method is focused on the air-carry ducts in the HVAC system. Next we will aimed at the drag reduction for water-carry piping system.

- 前期研究主要在减少配系统关键构件的局部阻力，长距离输送过程中的沿程阻力损失在阻力损失中也占据了重要的部分，应加强研究。
  The previous researches are mainly concerned to reduce the local resistance of the key components of the HVAC system. The friction losses during the long-distance pipeline system also contribute a great part of the resistance loss, and the research work should be further carried out in the future work.

- **Novel method has been proposed in reducing resistance and energy consumption for heating and cooling piping distribution system.**

# 谢谢大家！

# Thanks for your attention!

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