上海交通大学
SHANGHAI JIAO TONG UNIVERSITY

金属成形方面研究工作简介

李大永

上海交通大学 机械与动力工程学院

精密成形与知识工程研究所

总体情况

- **研究团队：**

  教授：彭颖红、李大永

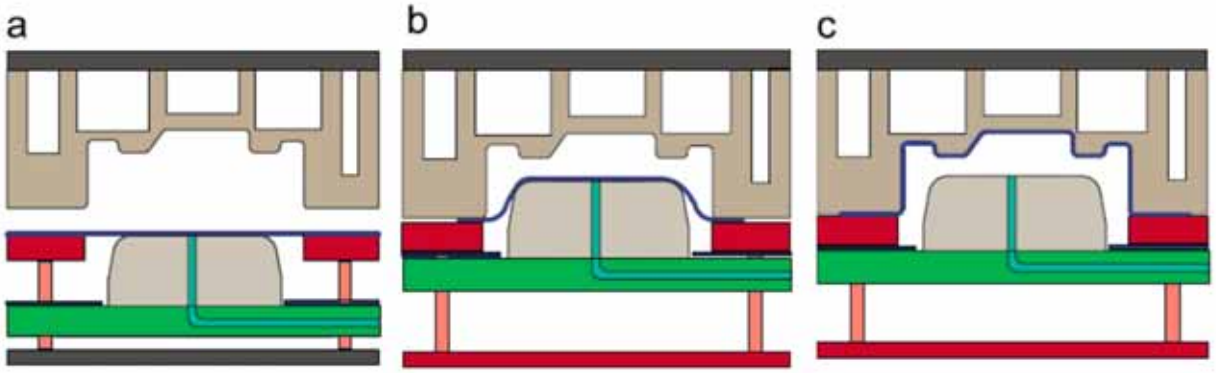
  副教授：唐鼎、汪华苗

  博士后2人, 博士/硕士研究生15人

- **研究方向:**
  - 轻量化材料先进成形理论、工艺技术与装备
  - 材料基因组理论与方法－多尺度建模与计算、智能化成形技术
  - 机械设计与成形制造中的CAD/CAE技术

冲压成形

轻量化板材成形

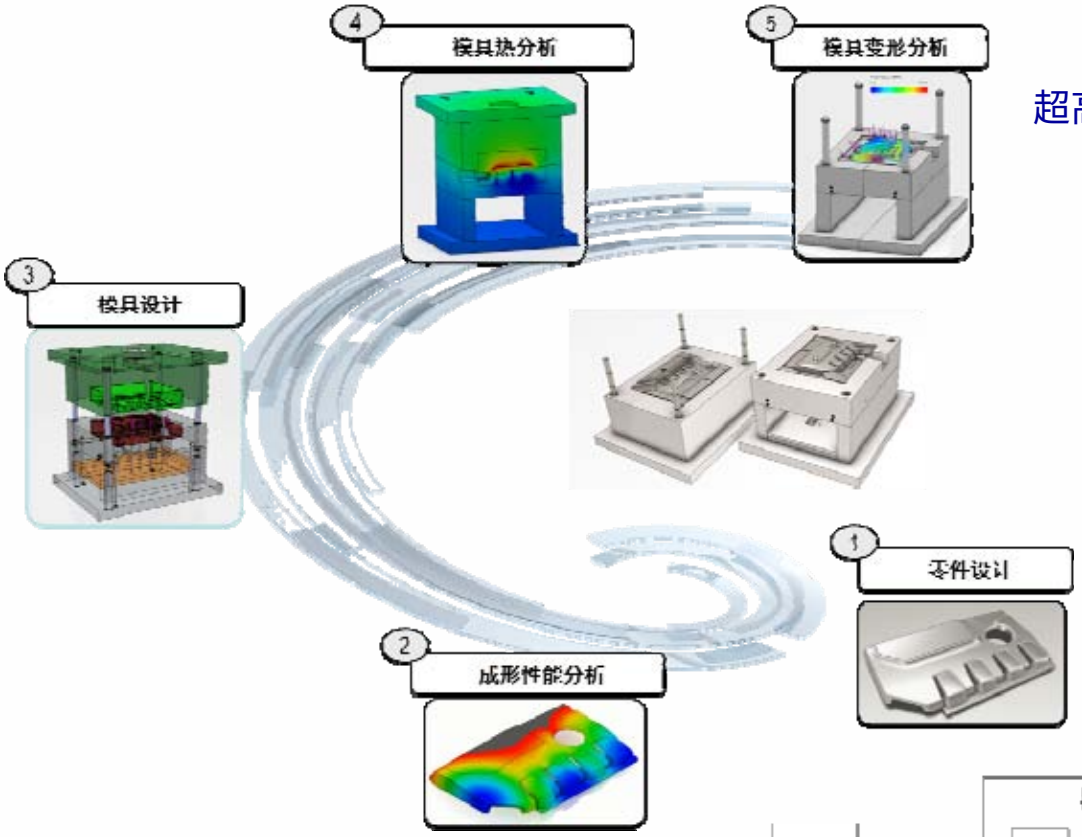


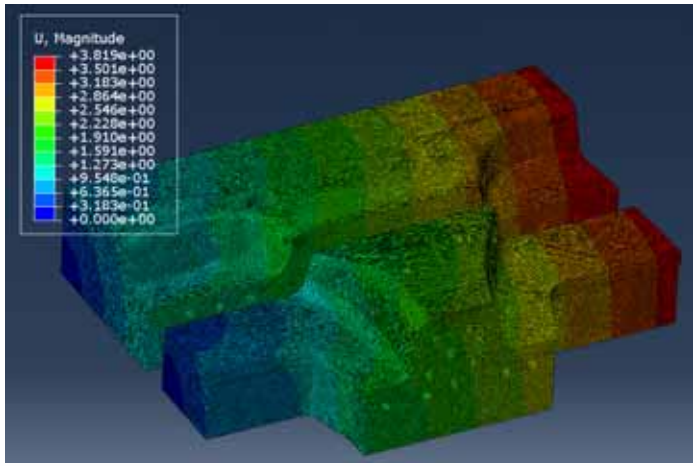
5182铝合金车身覆盖件

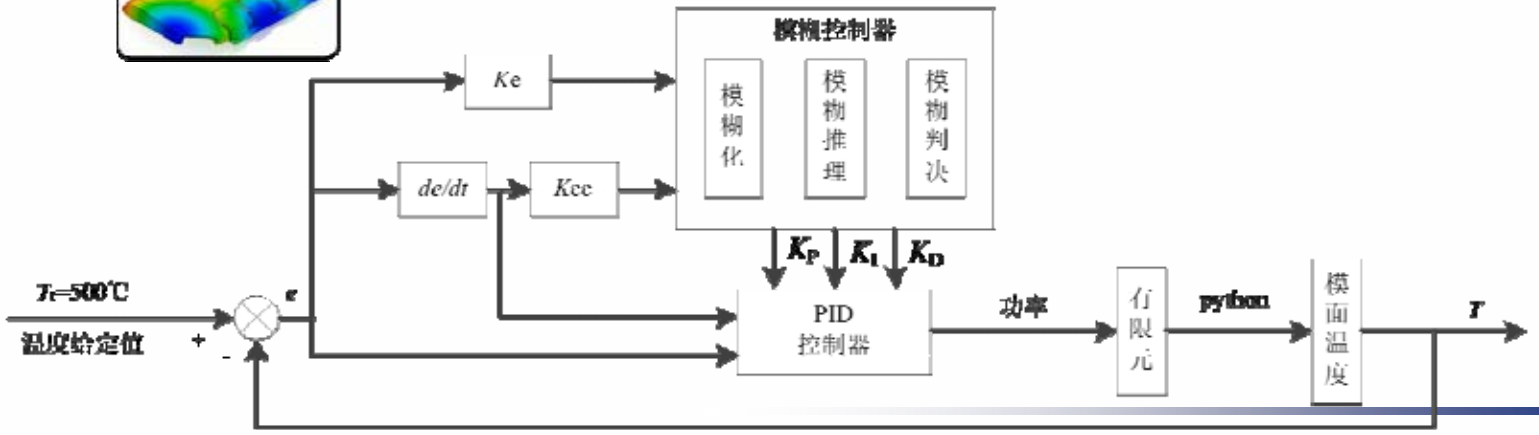
AZ31镁合金车身覆盖件

冲压成形

超高强车身结构件热冲压成形温度场分析和智能控制







挤压成形

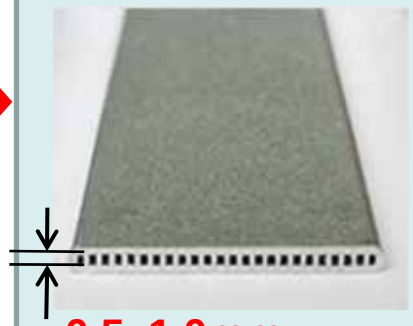
● 铝合金微通道扁管挤压模具与工艺

微通道换热器利用微尺度强化传热效应可显著提高空调能效，降低排放。

传统换热器：铜管 + 蛇形结构

10mm

微通道换热器：微通道铝管 + 平行流结构



0.5~1.0mm

环保优势
制冷剂用量减少达70%

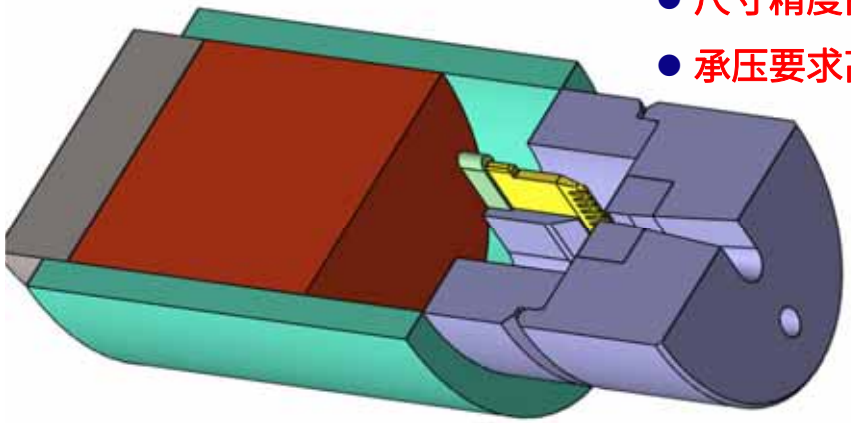
节能优势
换热效率提高30%以上

成本优势
减重60%，成本降低40%

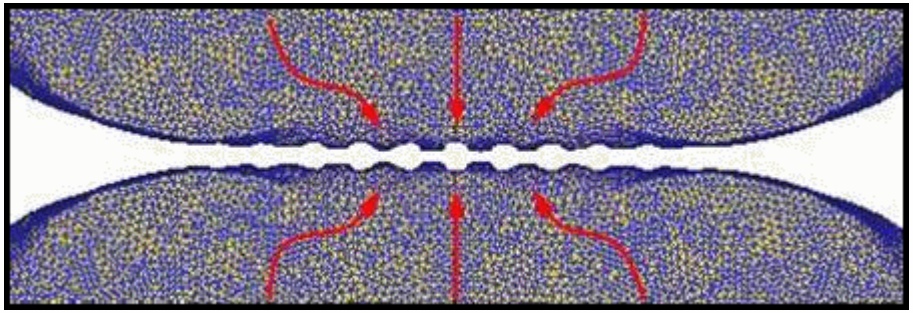
绿色制造优势
全铝结构，便于回收利用

挤压成形

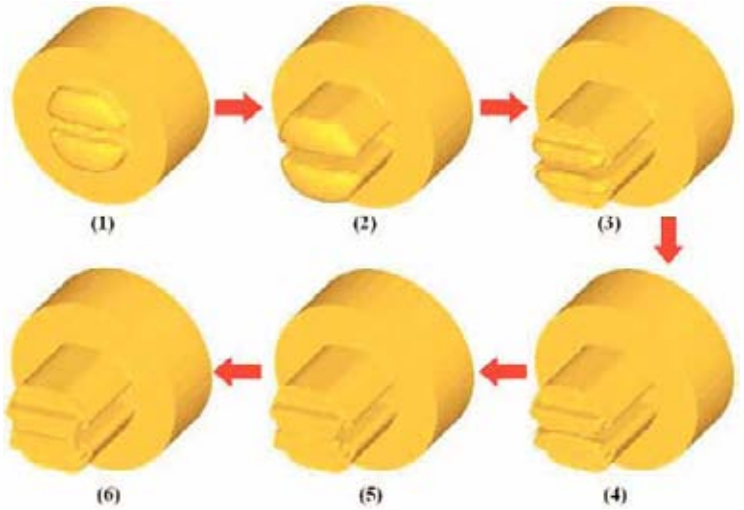
- 铝合金微通道扁管挤压焊合
  - 超大挤压比 (500:1)
  - 尺寸精度高 (±0.03mm)
  - 承压要求高 (20MPa)

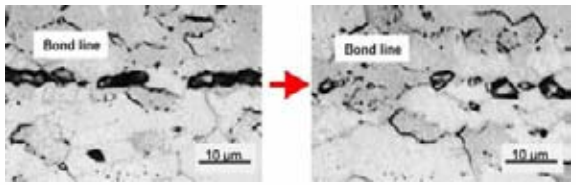


Extrusion process



Micro-channel hole welding process





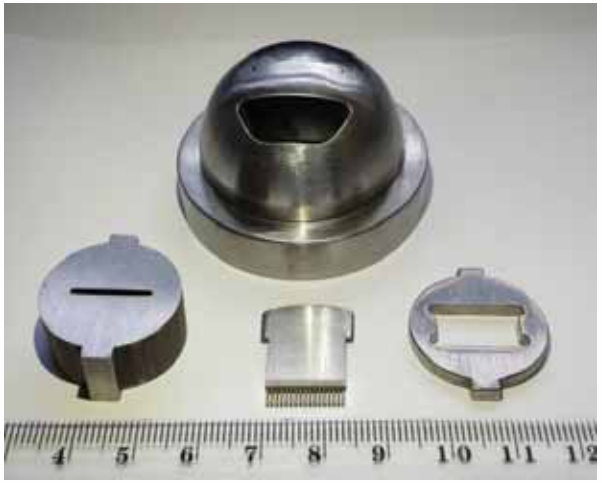
(a) $\varepsilon = 0.22$

Wall welding

挤压成形

- 铝合金微通道扁管模具开发

硬质合金镶嵌式模具



半球形倾斜流道模具

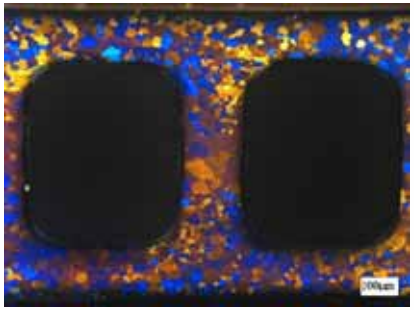
双层蝶形焊合室

局部涂层模具

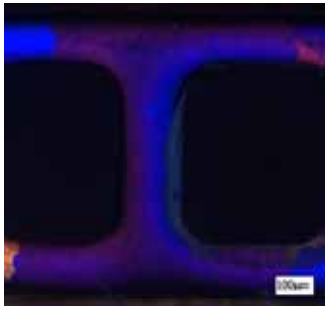
整体涂层模具

挤压成形

- 异常长大晶粒的取向分析



冷变形+退火



{0 0 1}<1 0 0> Cube - - Red
{1 1 2}<1 1 1> Copper - - Yellow
{0 0 1}<1 1 0> R-cube - - Green
{0 1 1}<2 1 1> Brass - - Fuchsia
{1 1 1}<u v w> Fibre - - Blue
{1 2 3}<6 3 4> S - - Aqua
{1 1 2}<1 1 0> B - - Teal
{1 1 0}<0 0 1> Goss - - Purple

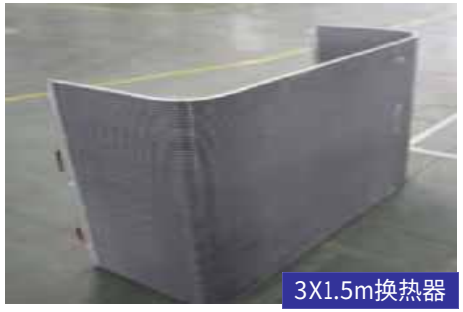
相关设备开发

- 微通道扁管检测与换热器无模折弯设备开发

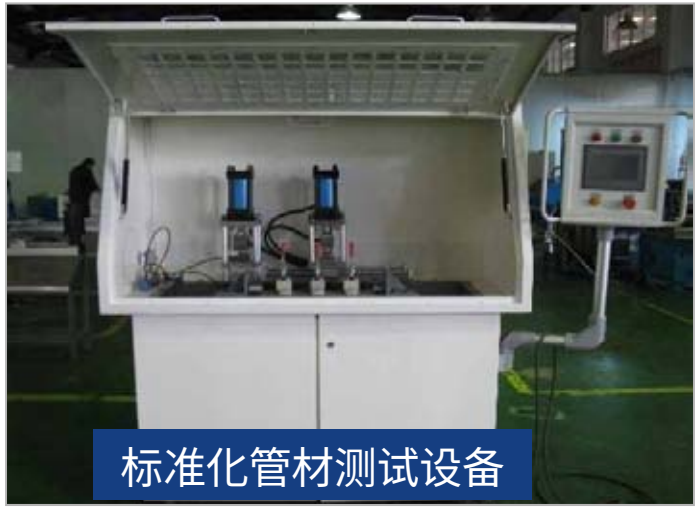
换热器整体无模折弯

适应多规格柔性生产， 翅片表面质量好

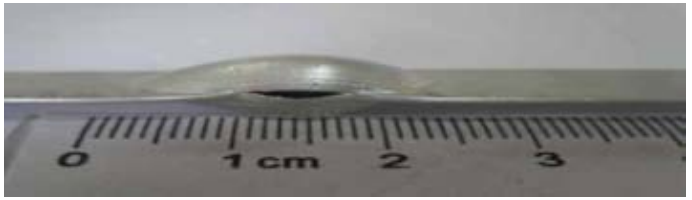
大型无模折弯设备



3X1.5m换热器

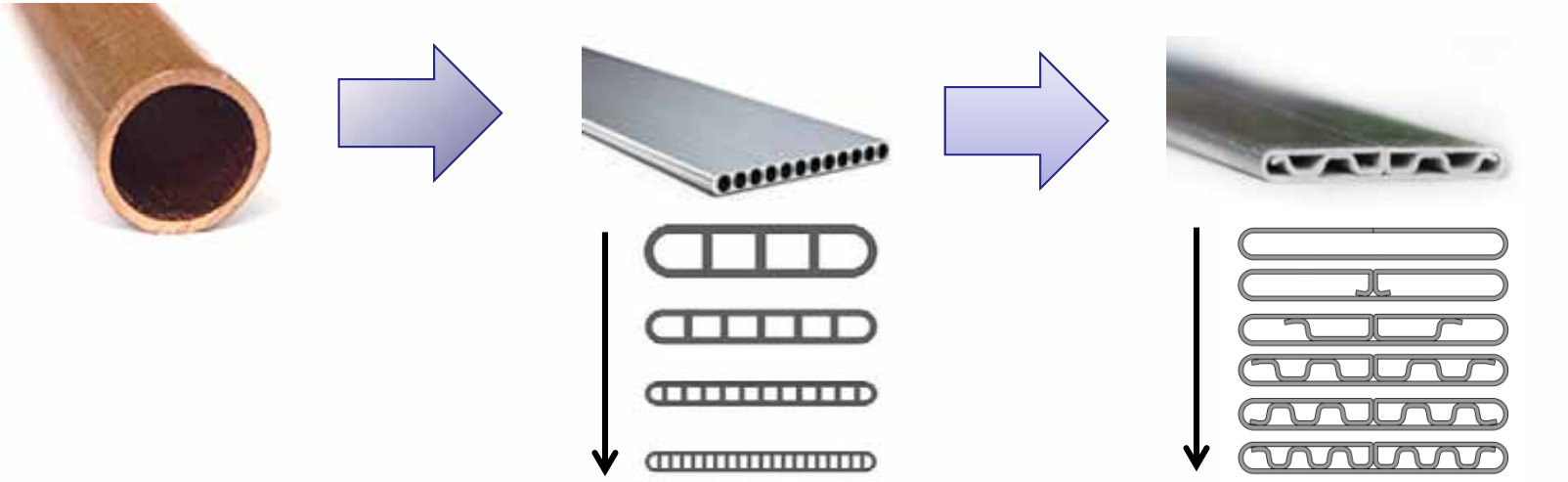


标准化管材测试设备



精密辊弯（冷弯）成形

热交换管的发展：



铜管　　挤压式微通道铝管　　折叠式微通道铝管

折叠管的优势（相对于挤压管）：

（1）复合铝带可根据工况设计，耐腐蚀性能提高80%以上；

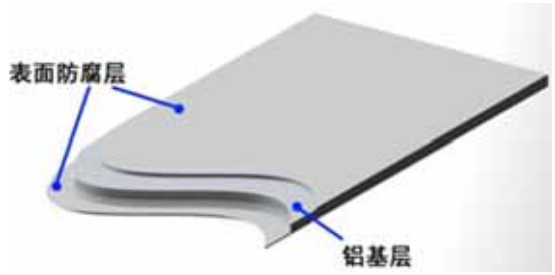
（2）管壁更薄、翅片采用非复合材料，成本可降低20%以上；

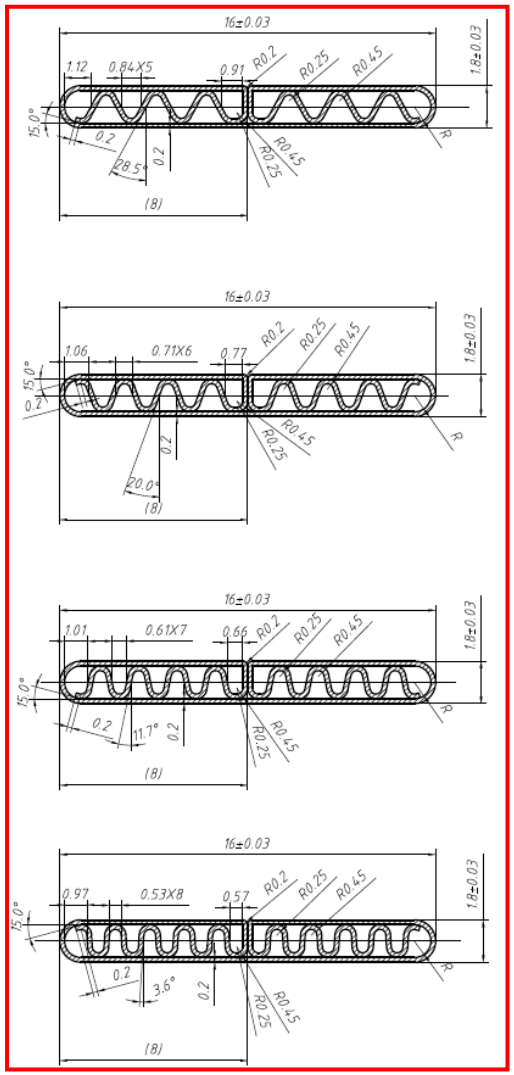
（3）生产过程为冷变形，能耗少、更加环保。

折叠管将可能取代挤压管成为下一代高性能换热产品

折叠微通道管型设计

- 外形尺寸
- 换热性能
- 承压性能
- 耐腐蚀性能
- 成本预算

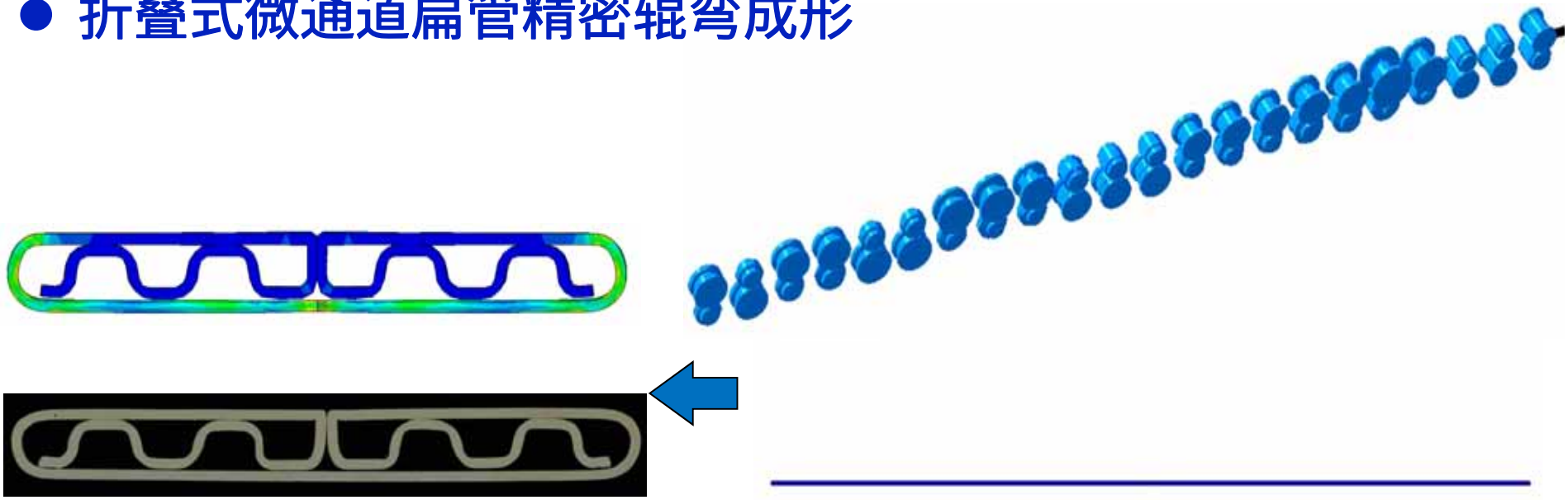


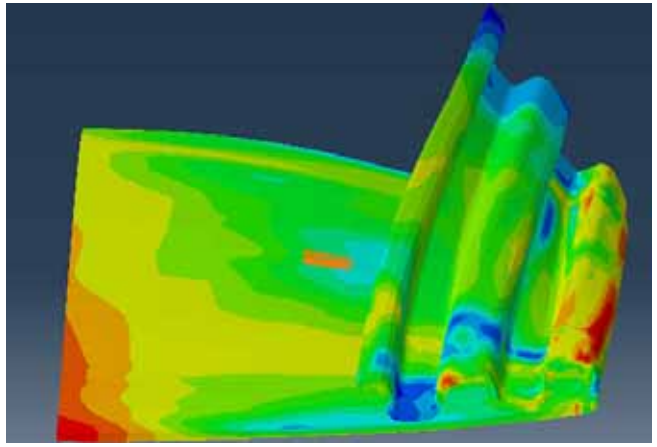


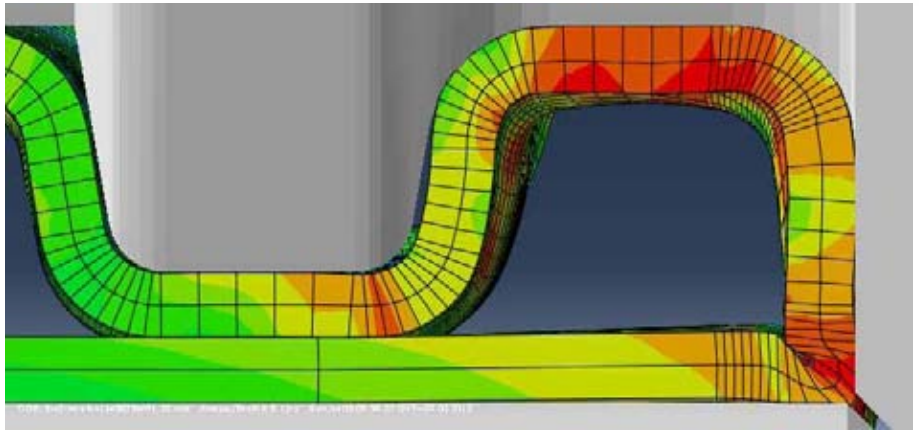
用户需求 → 原材料选择 → 管型设计

精密辊弯（冷弯）成形

- 折叠式微通道扁管精密辊弯成形

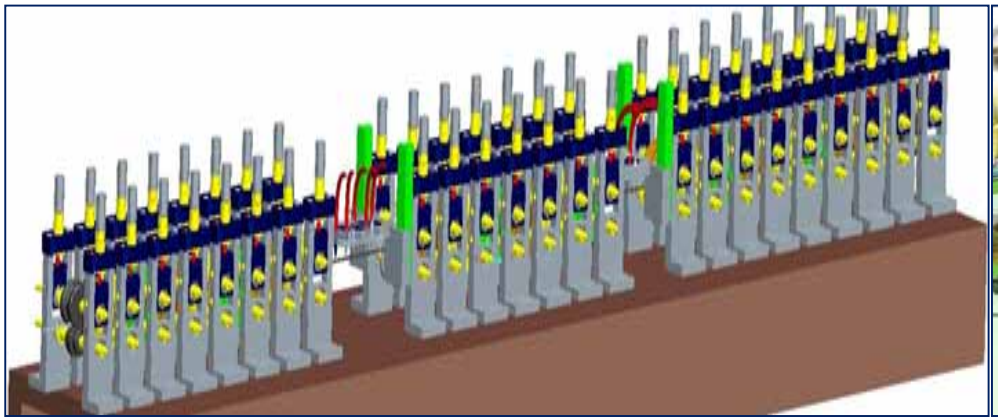






精密辊弯（冷弯）成形

- 折叠式微通道扁管精密辊弯



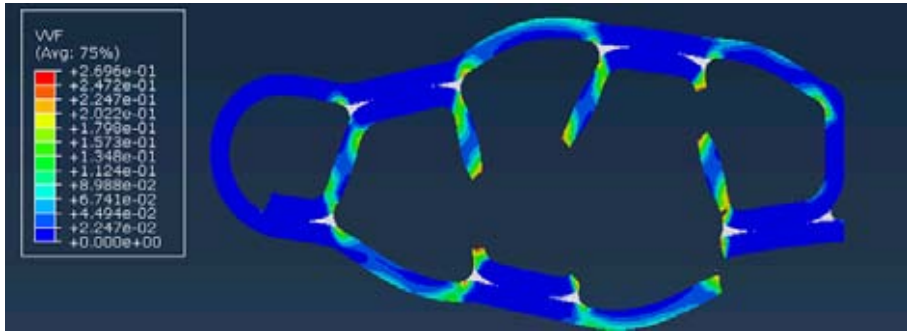
10孔微通道管

精密辊弯（冷弯）成形

- **折叠式微通道扁管检测**

压爆后扁管试样

压爆后扁管试样断面



仿真压爆效果，极限压力18.6MPa

实际压爆效果，极限压力18.2MPa

精密辊弯（冷弯）成形

专利、获奖情况


发 明 专 利 证 书


国家科学技术进步奖

证 书

为表彰国家科学技术进步奖获得者，特颁发此证书。

项目名称：微通道管材与换热器制造技术及其应用

奖励等级：二等

获 奖 者：上海交通大学

2014 年 12 月 22 日

证书号：2014-J-216-2-04-D01


中国国际工业博览会 2015 第17届

创新奖

INNOVATION AWARD

证 书

CERTIFICATE

上海交通大学，株式会社英田技术工程，南京凯微机电科技有限公司

Shanghai Jiaotong University, AIDA Engineering Co.,Ltd., Nanjing Carwin Mechanical&Electrical Technology Co.,Ltd.

折叠式微通道管辊弯成形制备工艺及装备

The Roll Forming Process and Equipment of Micro-channel Folded Tube

荣获第十七届中国国际工业博览会创新奖

is awarded

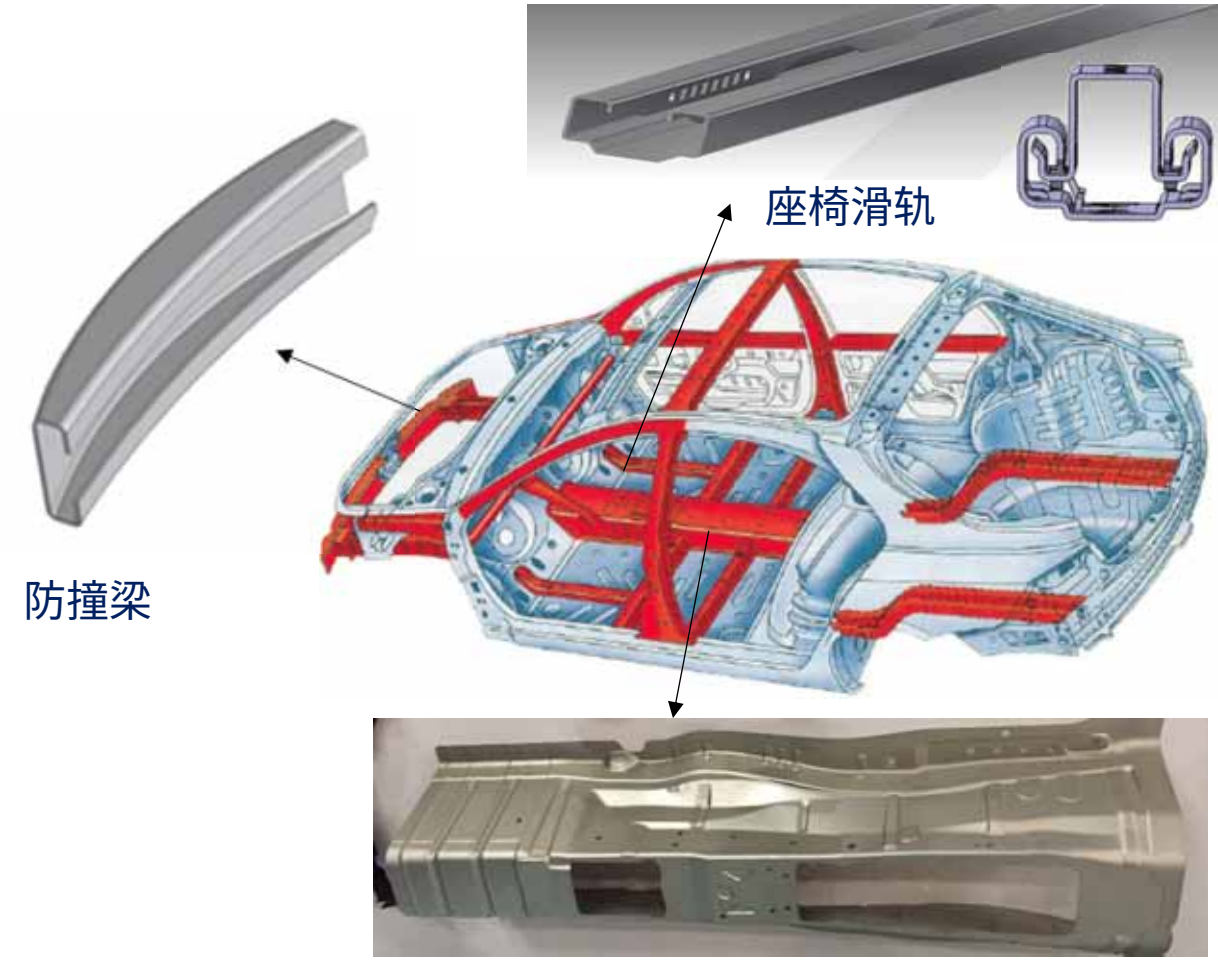
INNOVATION AWARD

by The 17th Session China International Industry Fair

中国国际工业博览会委会

辊冲复合成形

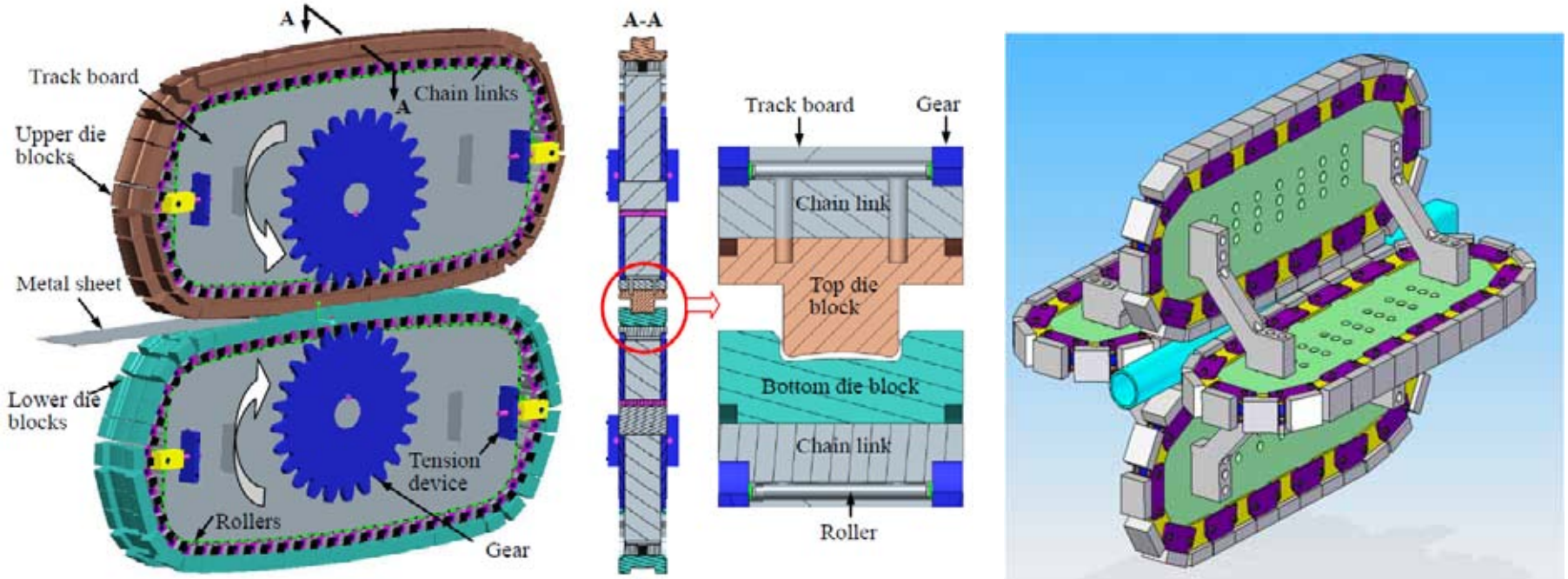
- 高强度车身结构件制造面临的挑战



- 高强度：强度>1000MPa
- 高精度：尺寸精度0.1mm
- 小圆角：最小半径0.5mm
- 截面变化复杂

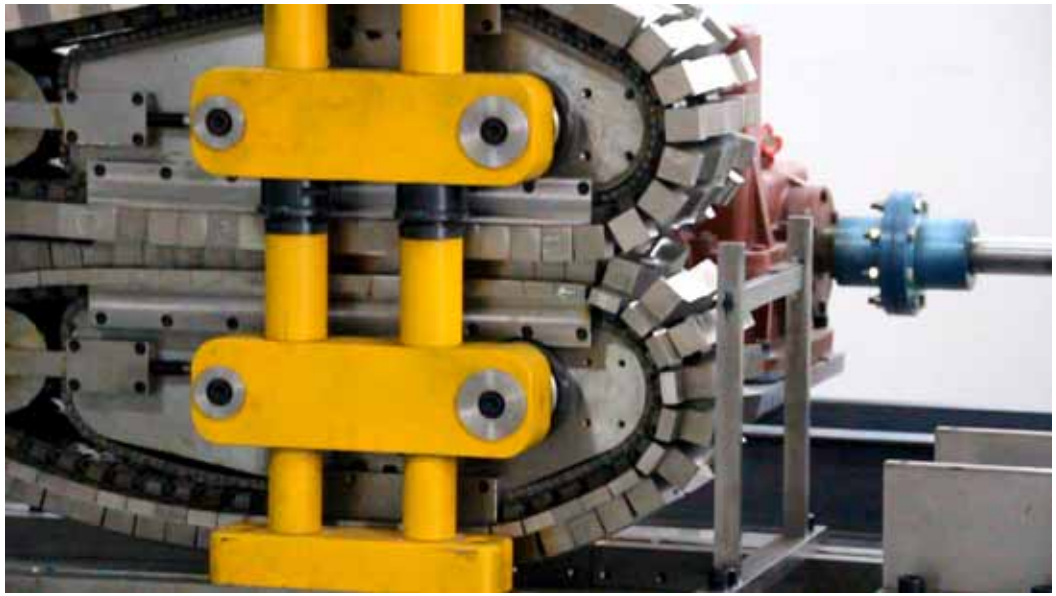
辊冲复合成形

- 链模式辊冲复合成形--一种新兴的柔性成形技术



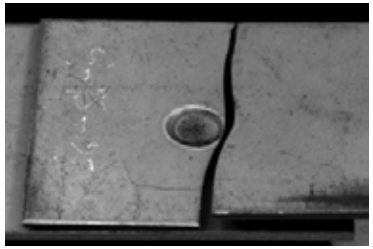
与澳大利亚昆士兰大学、宝钢、福特汽车等合作，针对辊冲复合成形机理、成形设备、成形工艺设计开展系统研究。

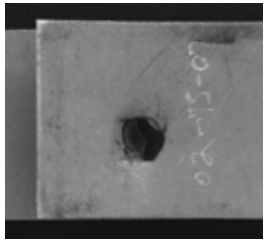
辊冲复合成形

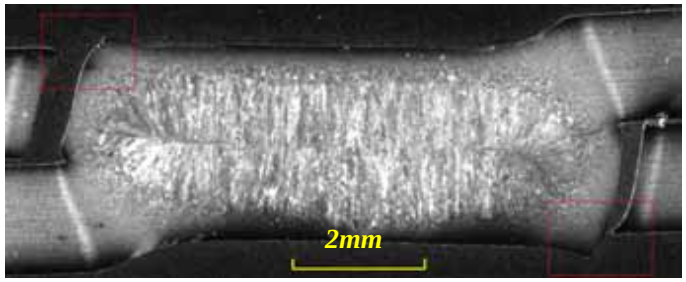


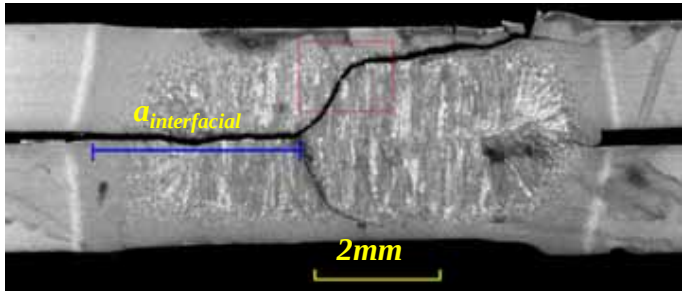
车身零件连接接头的疲劳强度计算

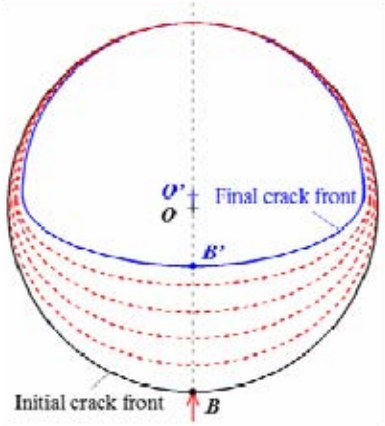
- 接头结构的疲劳分析－点焊接头

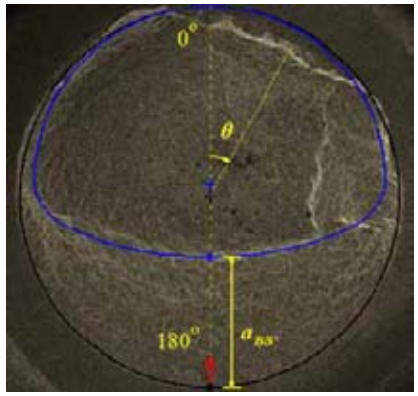


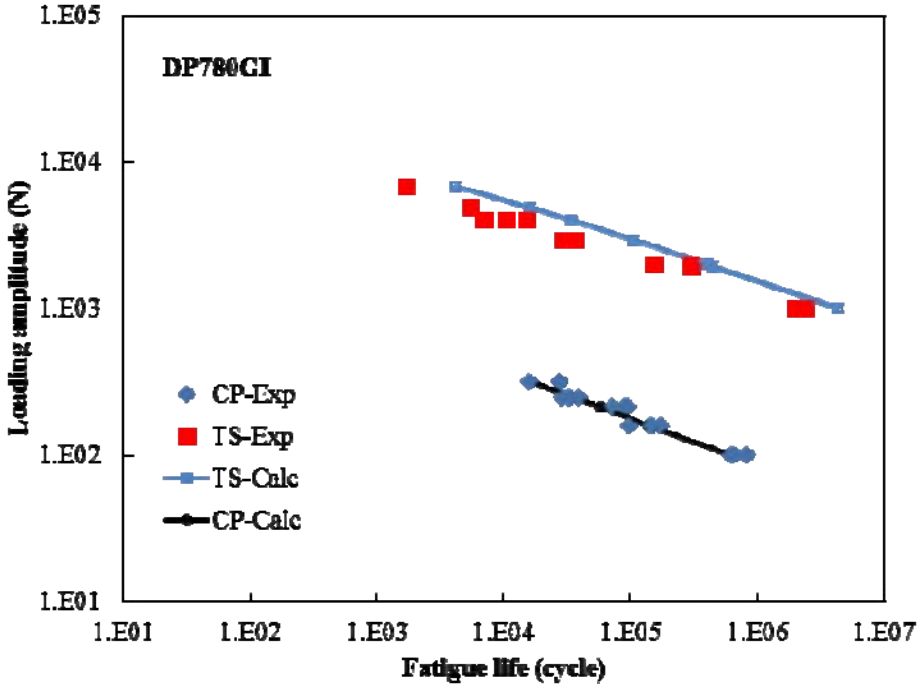








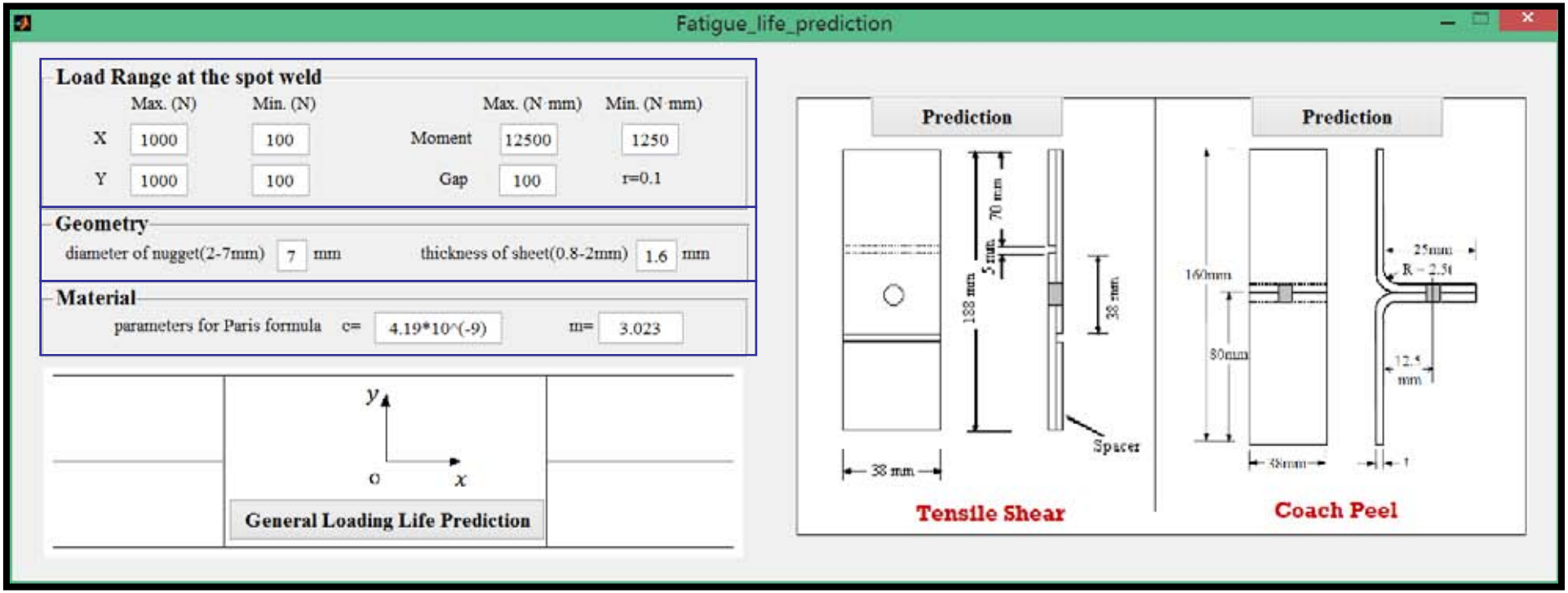




International Journal of Fatigue (**2018**)

接头的疲劳强度计算

- 接头结构的疲劳分析软件



- **Input：**

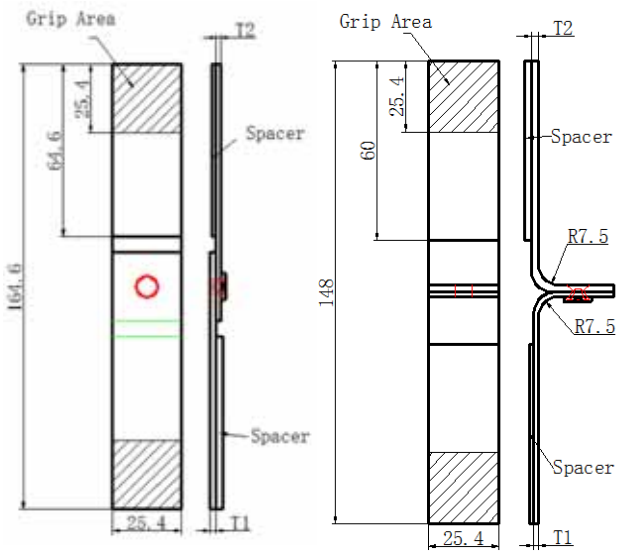
  Loading condition at the spot weld (force and moment)

  Geometric parameters (nugget diameter, width, thickness of sheet)

  Material parameters (the crack propagation rates: c, m)

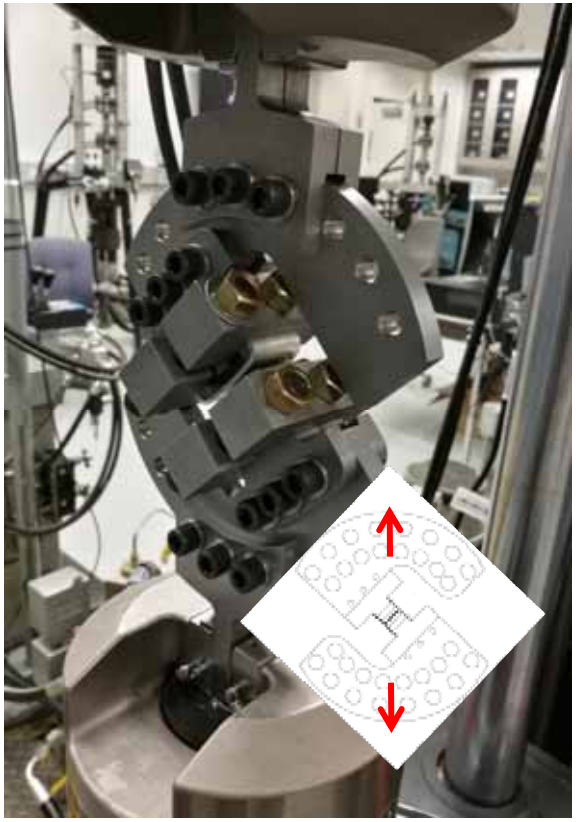
接头的疲劳强度计算

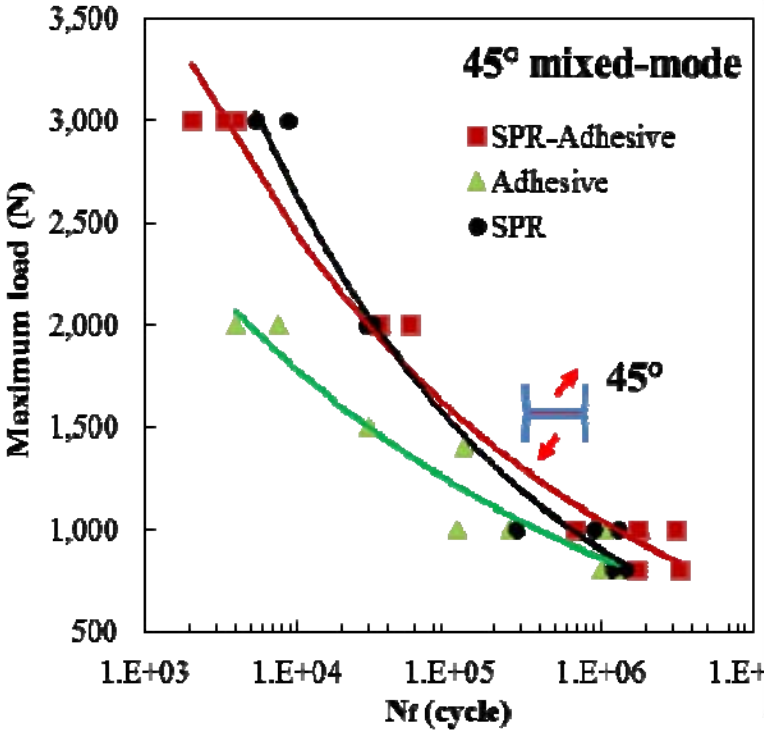
- 接头结构的疲劳分析－SPR+Adhesive

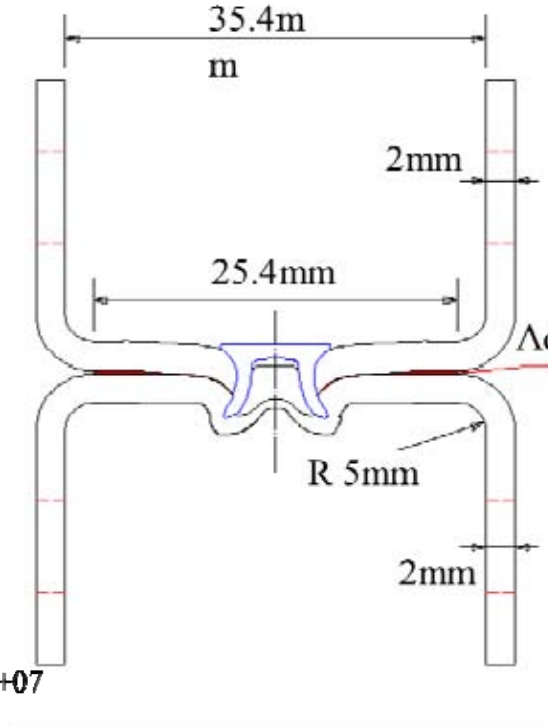


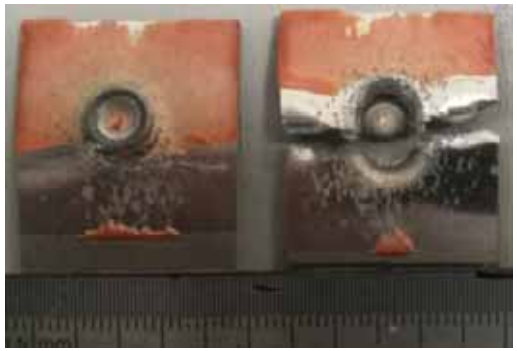
Tensile shear　　Coach peel

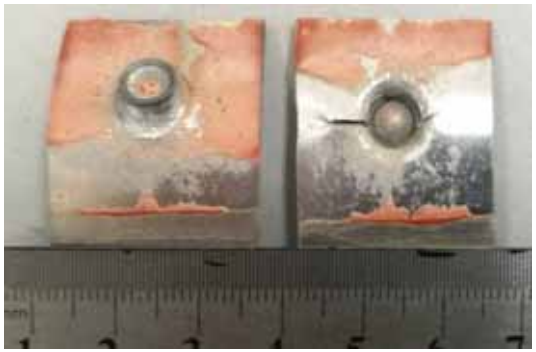
接头的疲劳强度计算

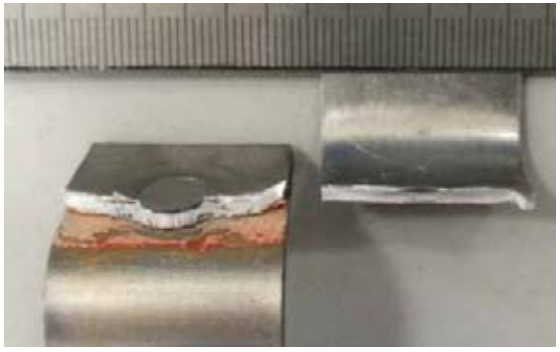



45° mixed-mode
SPR-Adhesive
Adhesive
SPR
45°
Maximum load (N)
3,500
3,000
2,500
2,000
1,500
1,000
500
1.E+03
1.E+04
1.E+05
1.E+06
1.E+07
Nf (cycle)


35.4m
m
2mm
25.4mm
R 5mm
2mm

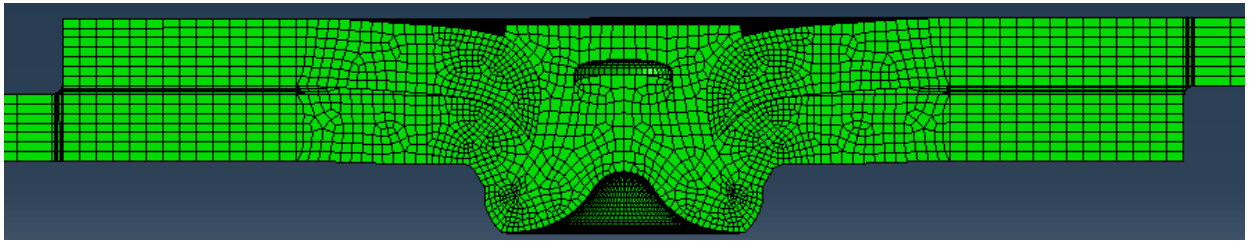


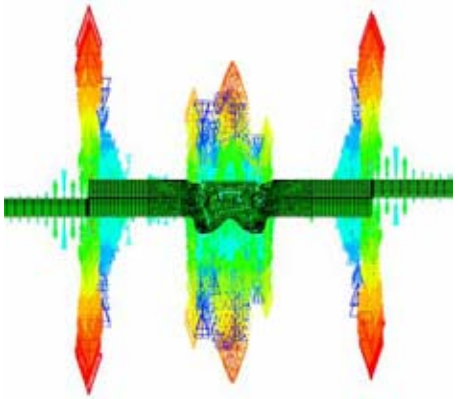


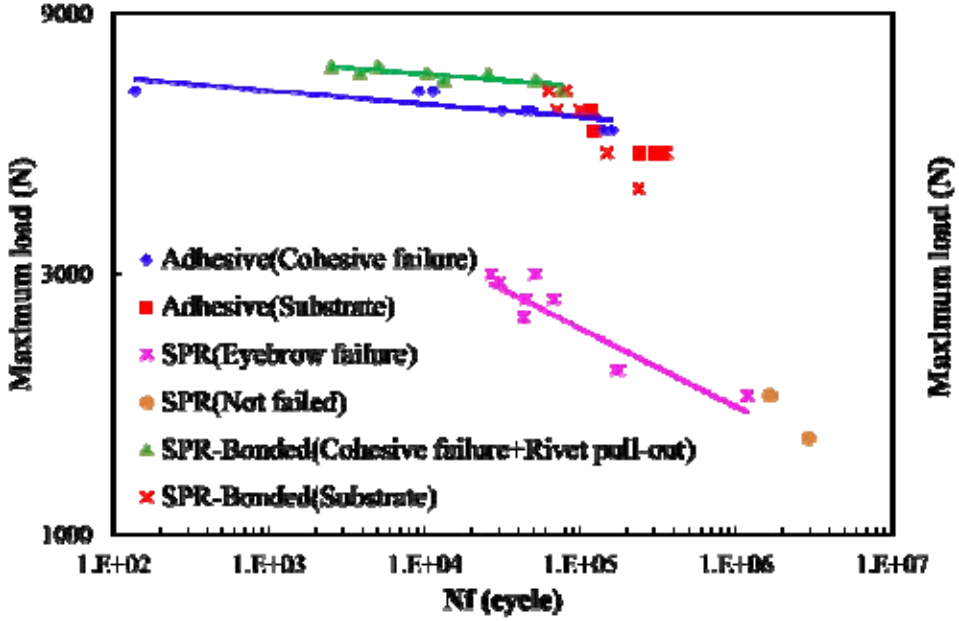


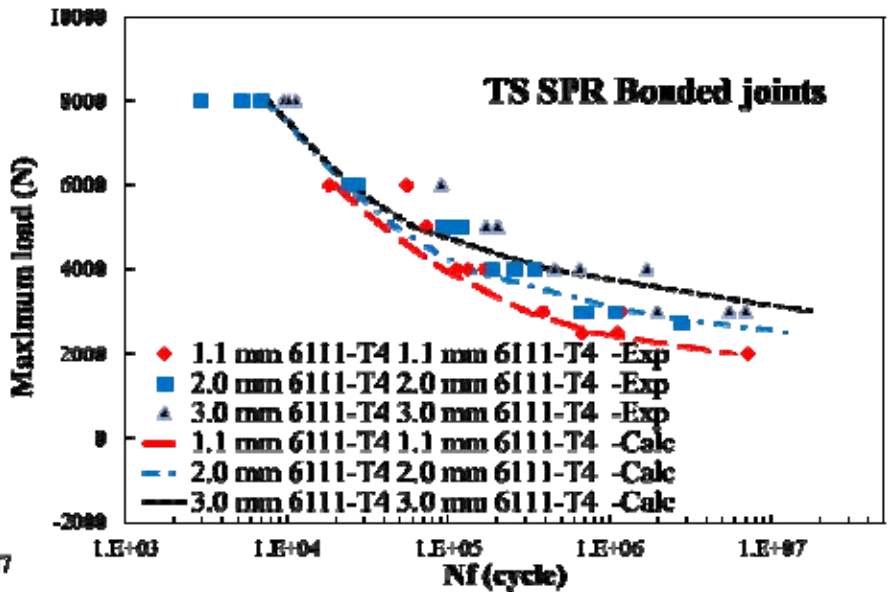
接头的疲劳强度计算

- 接头结构的疲劳分析－SPR+Adhesive

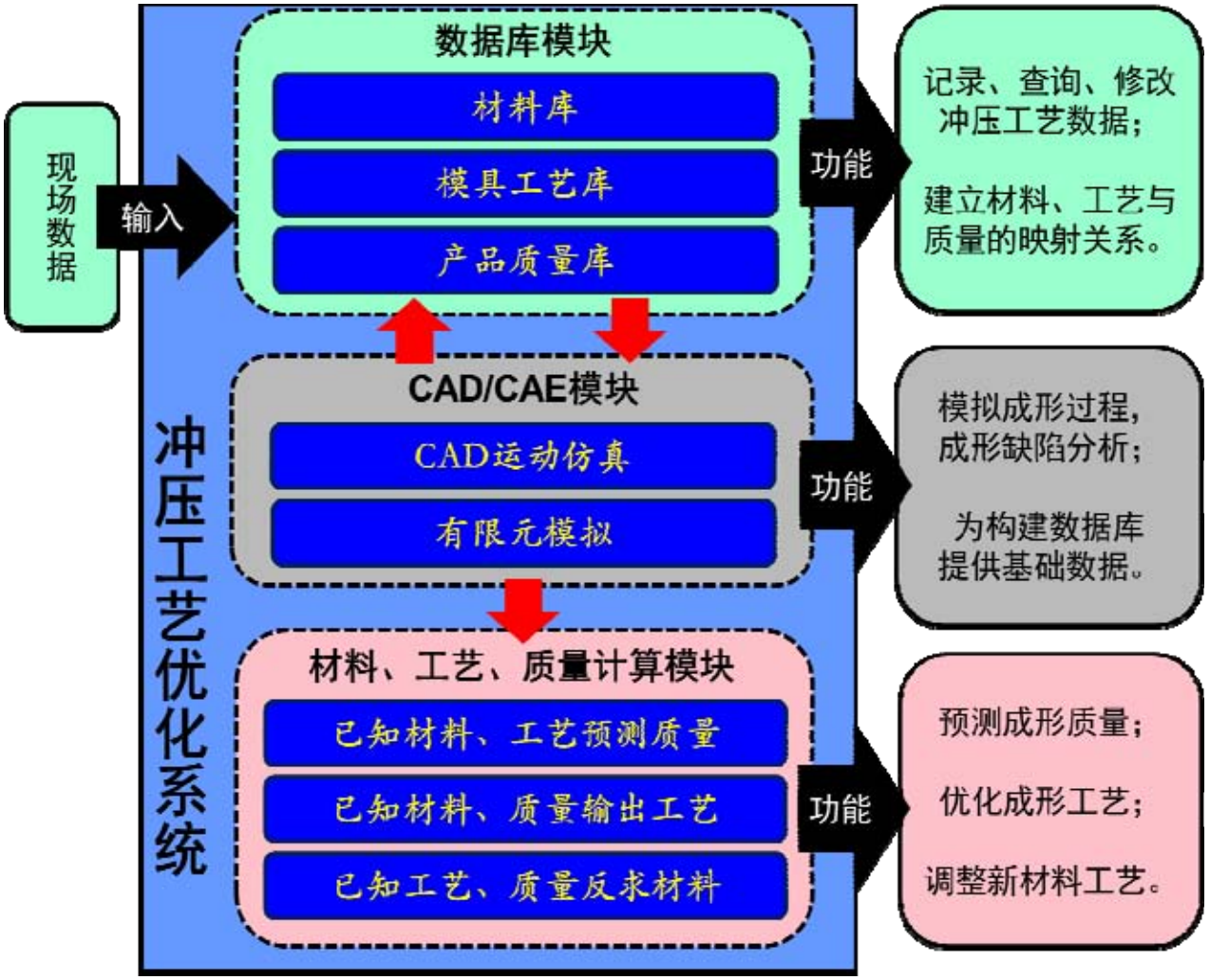


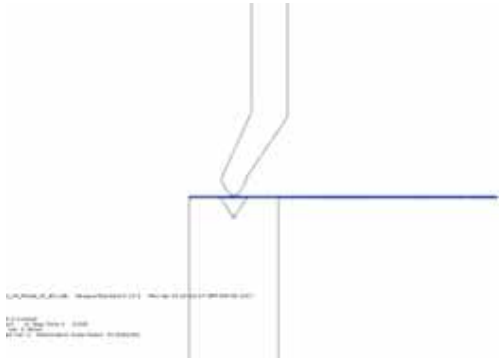


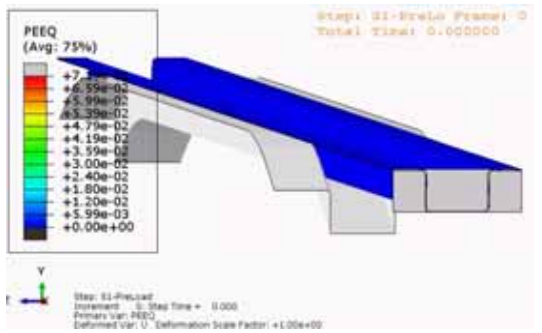




高铁/城铁零件制造工艺智能化设计

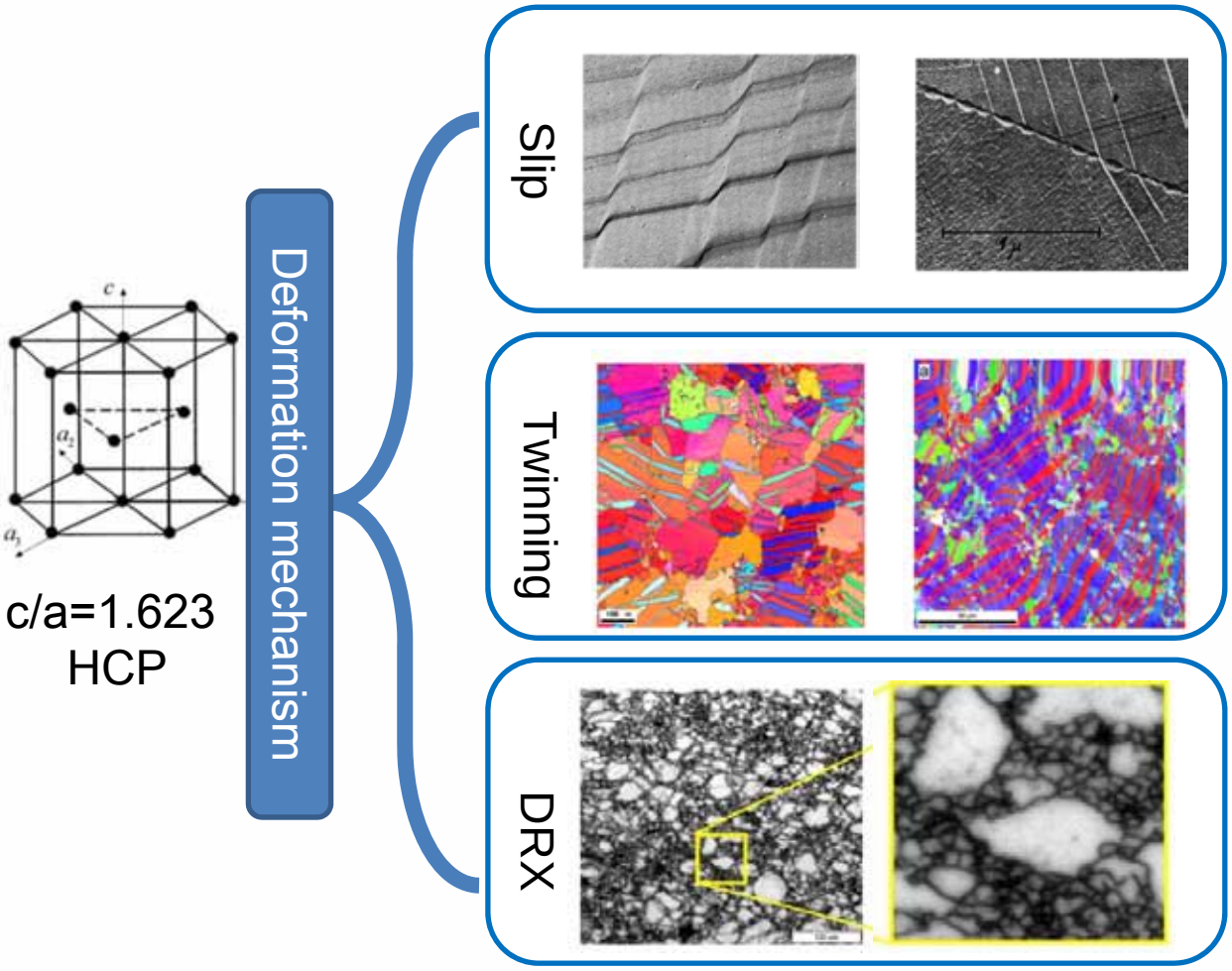






晶体塑性-动态再结晶模型

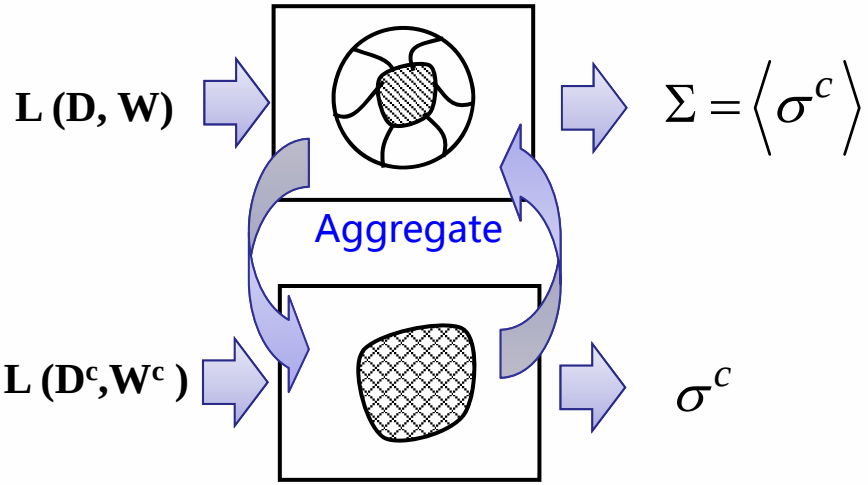
- 镁合金变形的晶体塑性模拟

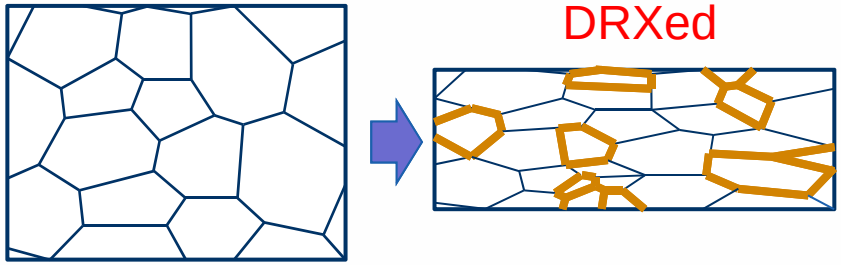


International Journal of Plasticity (2016, 2017, 2018), Journal of Alloys and Compounds (2018), Materials Science and Engineering: A (2018)

晶体塑性-动态再结晶模型

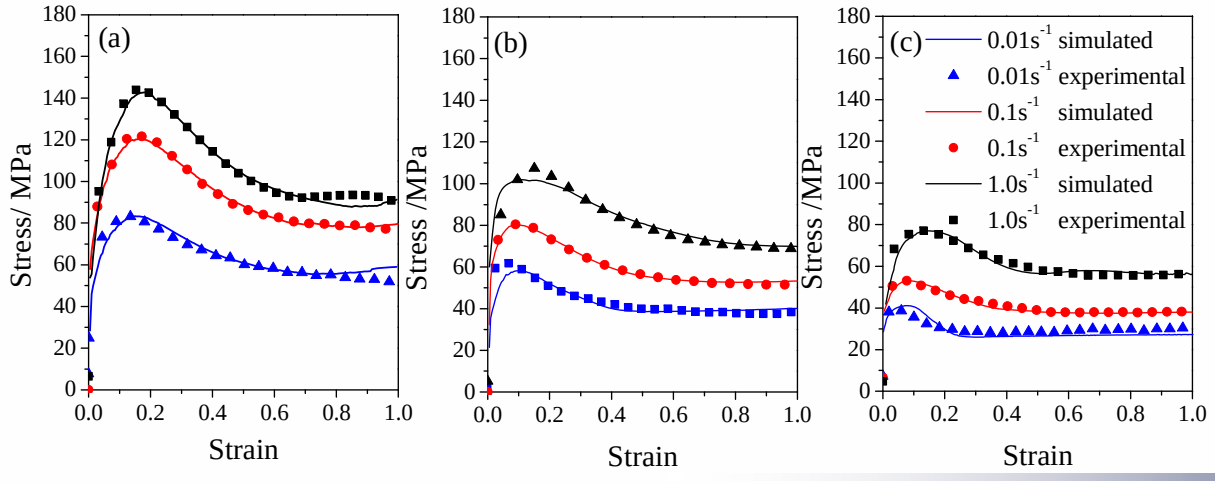
- 镁合金变形的晶体塑性模拟





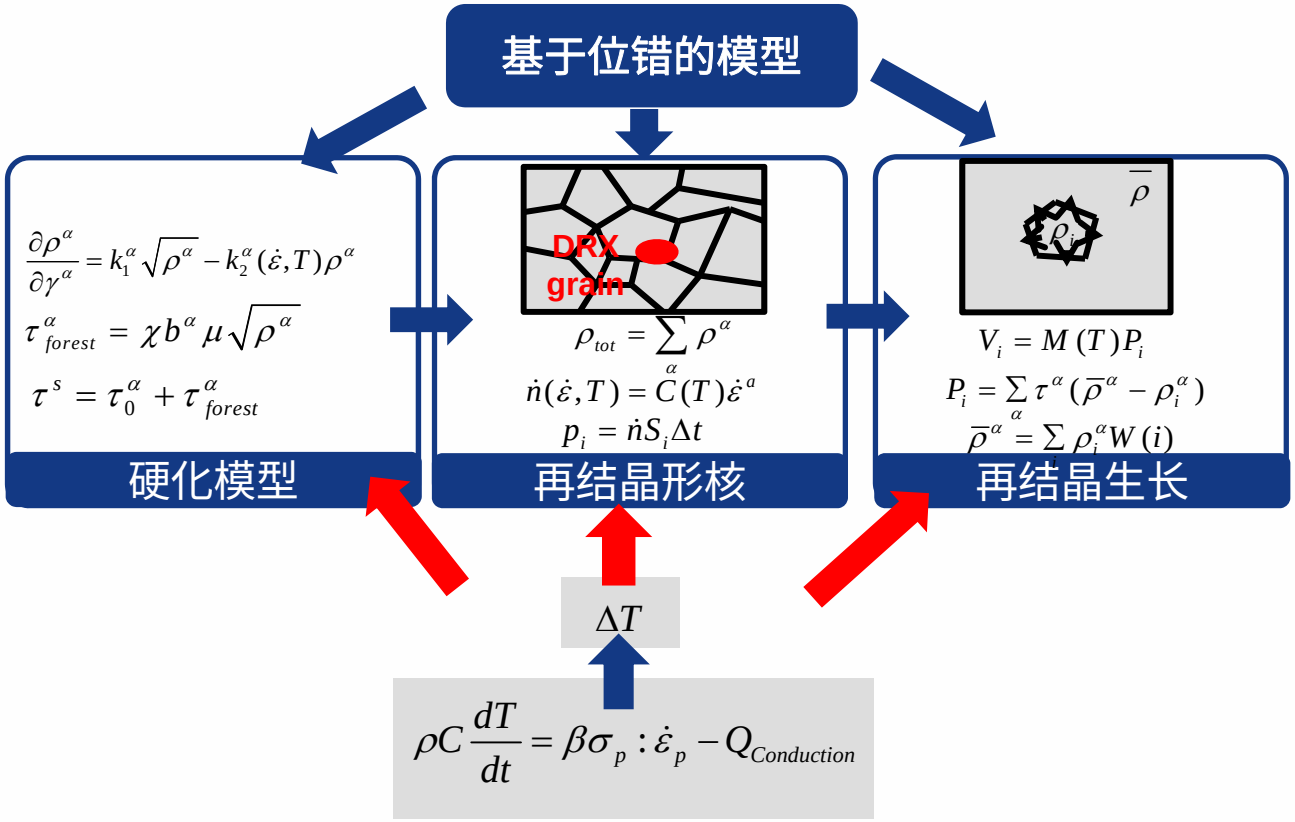
DRX grains

Original grains



晶体塑性-动态再结晶模型

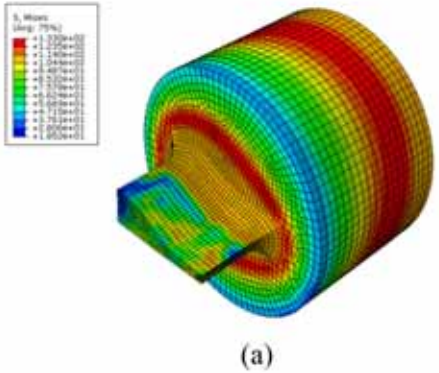
- **热力耦合的VPSC-DRX模型**

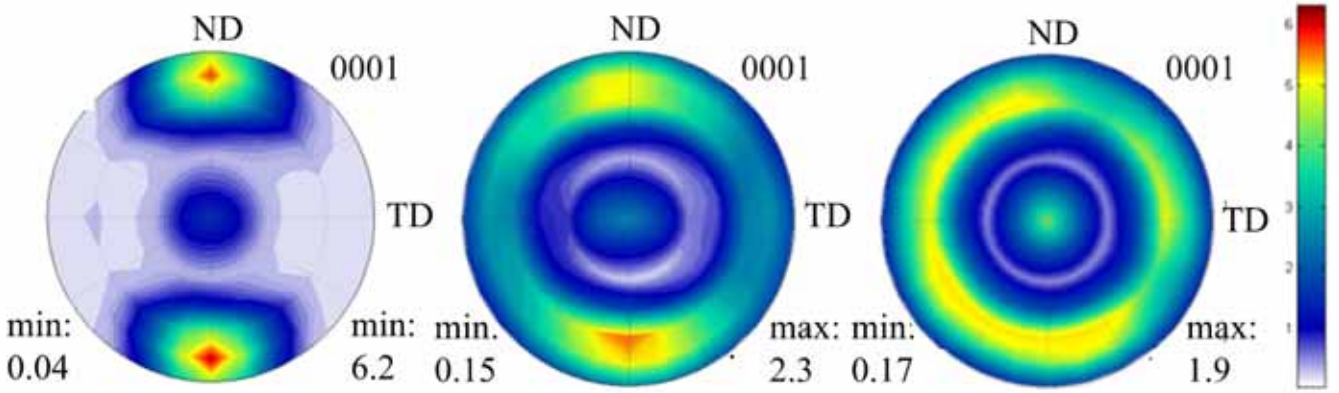


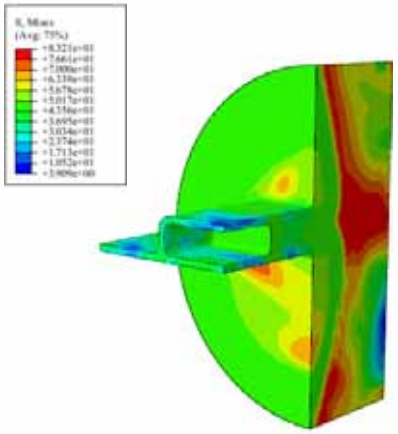
- 将材料变形热及热传导规律模型与VPSC-DRX模型耦合。

晶体塑性-动态再结晶模型

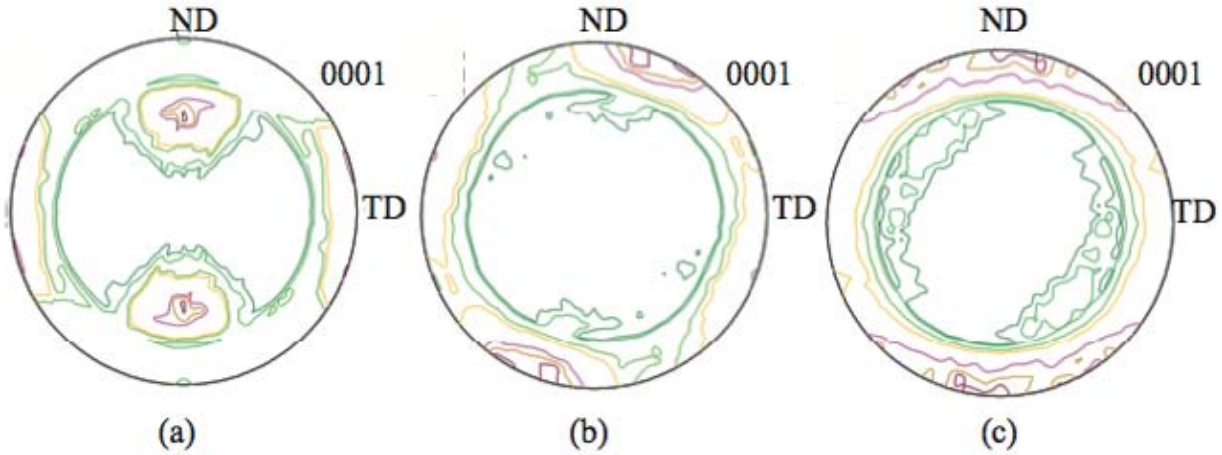
- 镁合金变形的晶体塑性模拟







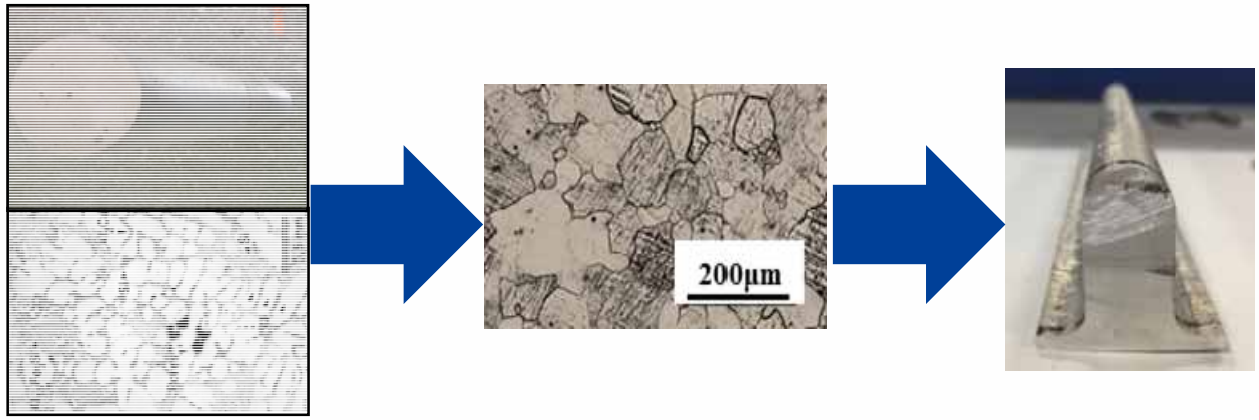
Mg extrusion



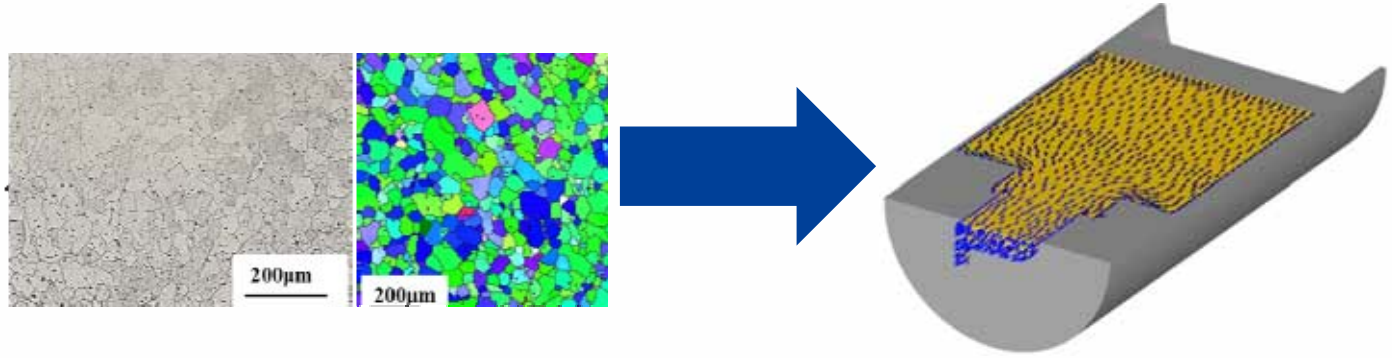
Texture development simulation

晶体塑性-动态再结晶模型

- **宏微观集成计算**



铸态材料　　材料微观表征　　实际零部件

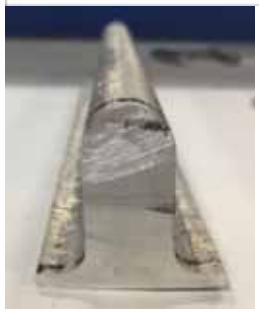


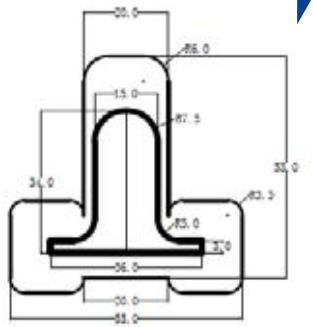
TM-VPSC-DRX模型描述的材料微观变形规律　　有限元宏观模型描述

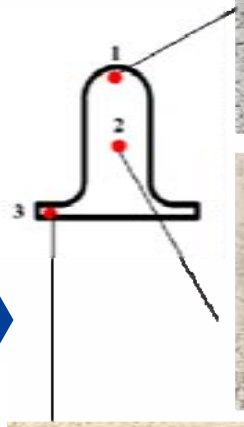
- 宏微观集成计算立足于定量描述材料微观组织信息、加工工艺和产品性能之间的关系。

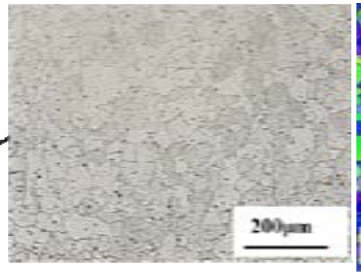
晶体塑性-动态再结晶模型

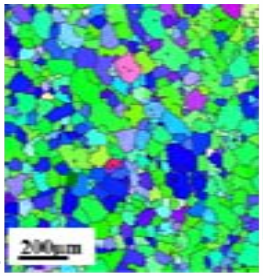
- **型材挤压试验**

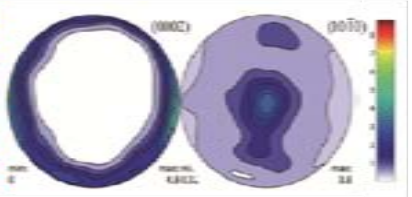




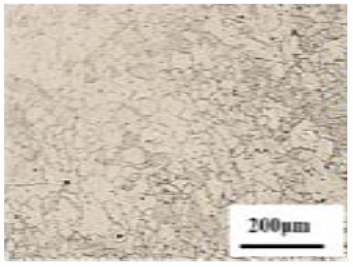


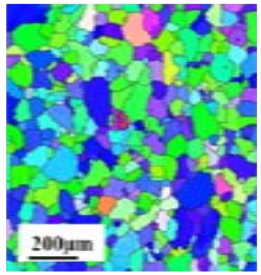


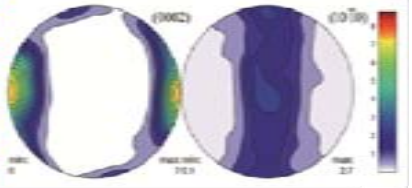




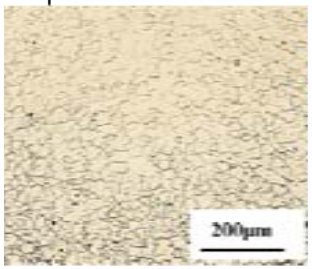
类似圆棒挤压织构

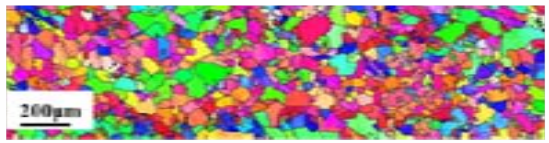


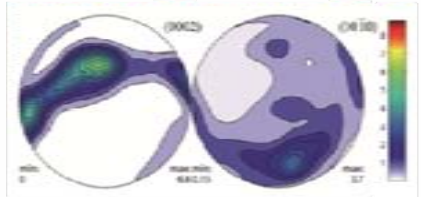


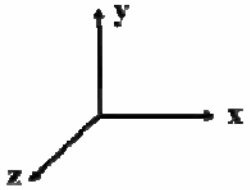


类似平面压缩织构







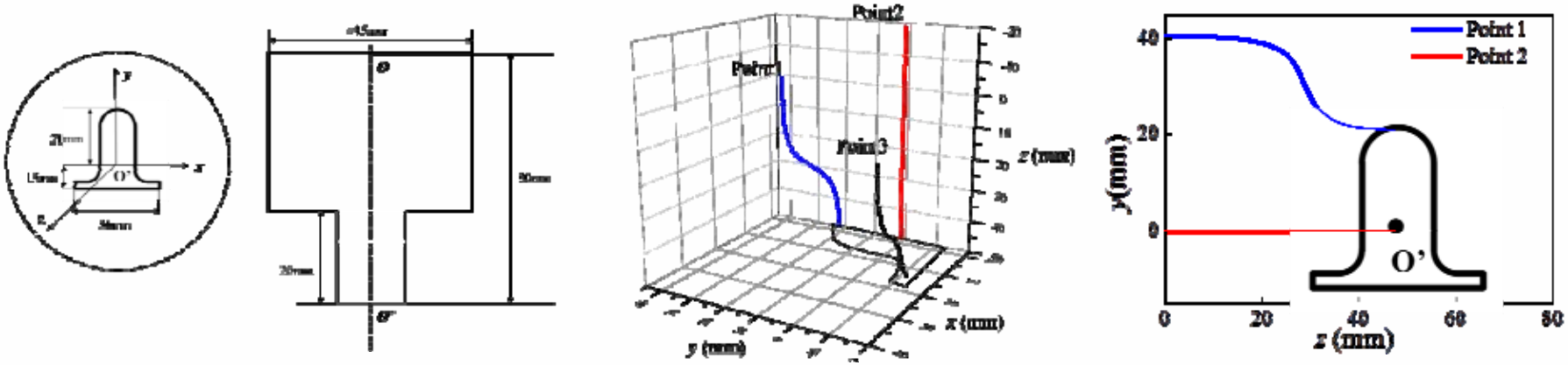


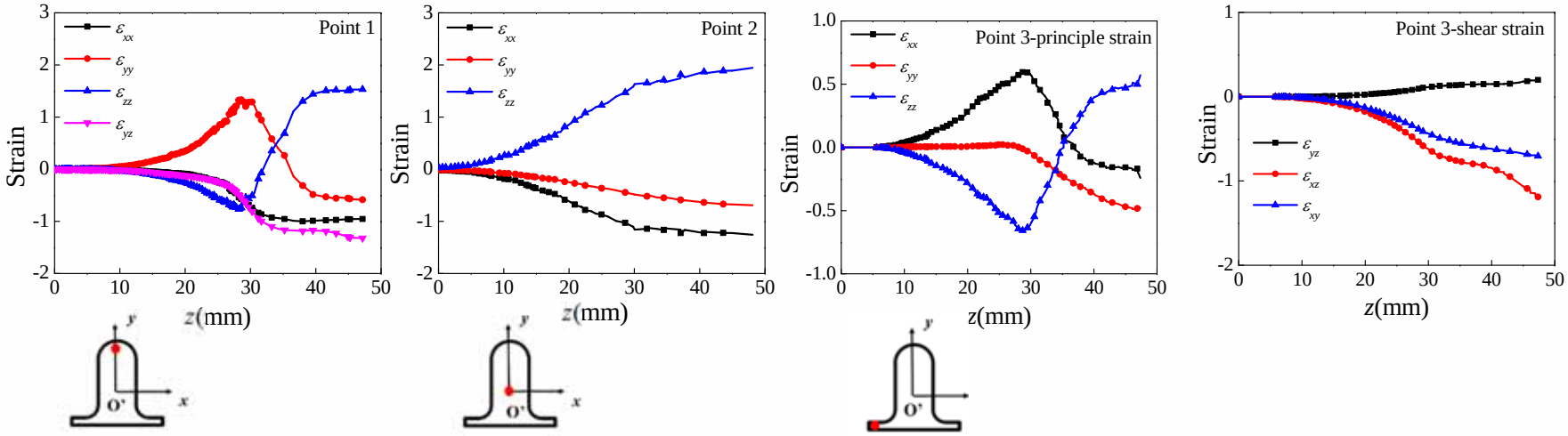
多向切应变变形织构

- 在673K，0.5mm/s速度下进行合金型材挤压试验，型材不同变形区域显示了不同的微观组织与织构演化规律。

晶体塑性-动态再结晶模型

- **宏微观集成计算**





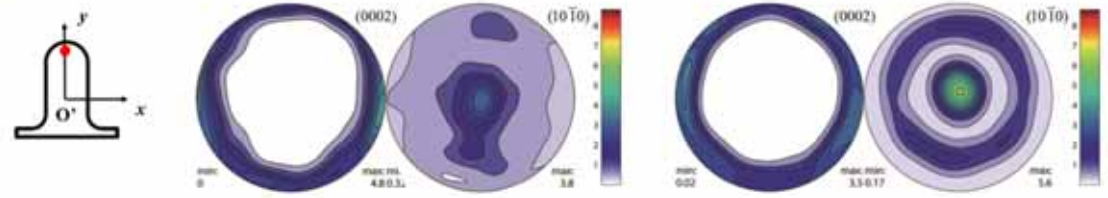
- 有限元模型获取材料应变路径。

晶体塑性-动态再结晶模型

- **宏微观集成计算**

试验 (0002) (10$\bar{1}$0)　　模拟 (0002) (10$\bar{1}$0)

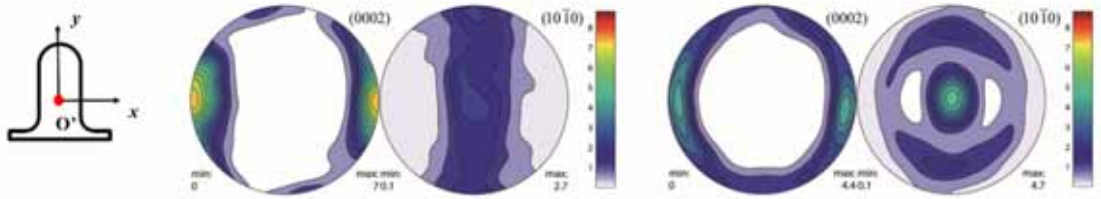
类似圆棒挤压织构



织构结果对比

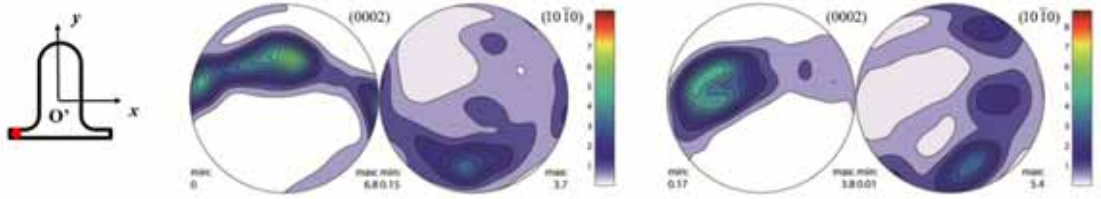
(0002) (10$\bar{1}$0)　　(0002) (10$\bar{1}$0)

类似平面压缩织构



(0002) (10$\bar{1}$0)　　(0002) (10$\bar{1}$0)

多向切应变变形织构



- 数值模拟结果反映了型材挤压不同变形位置材料的特征织构演化规律。

谢 谢！

Prof. Li Dayong

Affiliation: Shanghai Jiao Tong University

Address: 800 Dongchuan Road, Shanghai, China

Tel.: +86-021-34206313

Email: dyli@sjtu.edu.cn