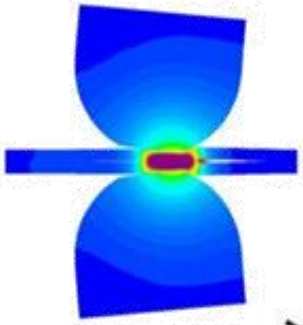
Simufact.welding
—焊接结构模拟仿真

焊接模拟的领域



工艺

焊缝熔池形状
局部焊接温度场
工艺效率
工艺稳定性

SimWeld

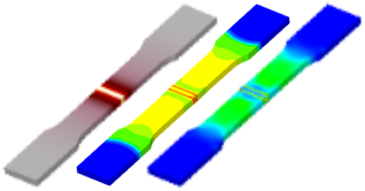
等效热源模型

坡口间隙、热边界条件

焊接仿真

相变潜热
热物理属性

熔池材料成分



结构

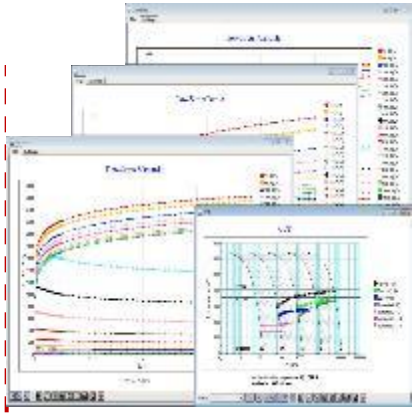
残余应力
变形
强度
刚度

微观应力

相变应变、 机械性能

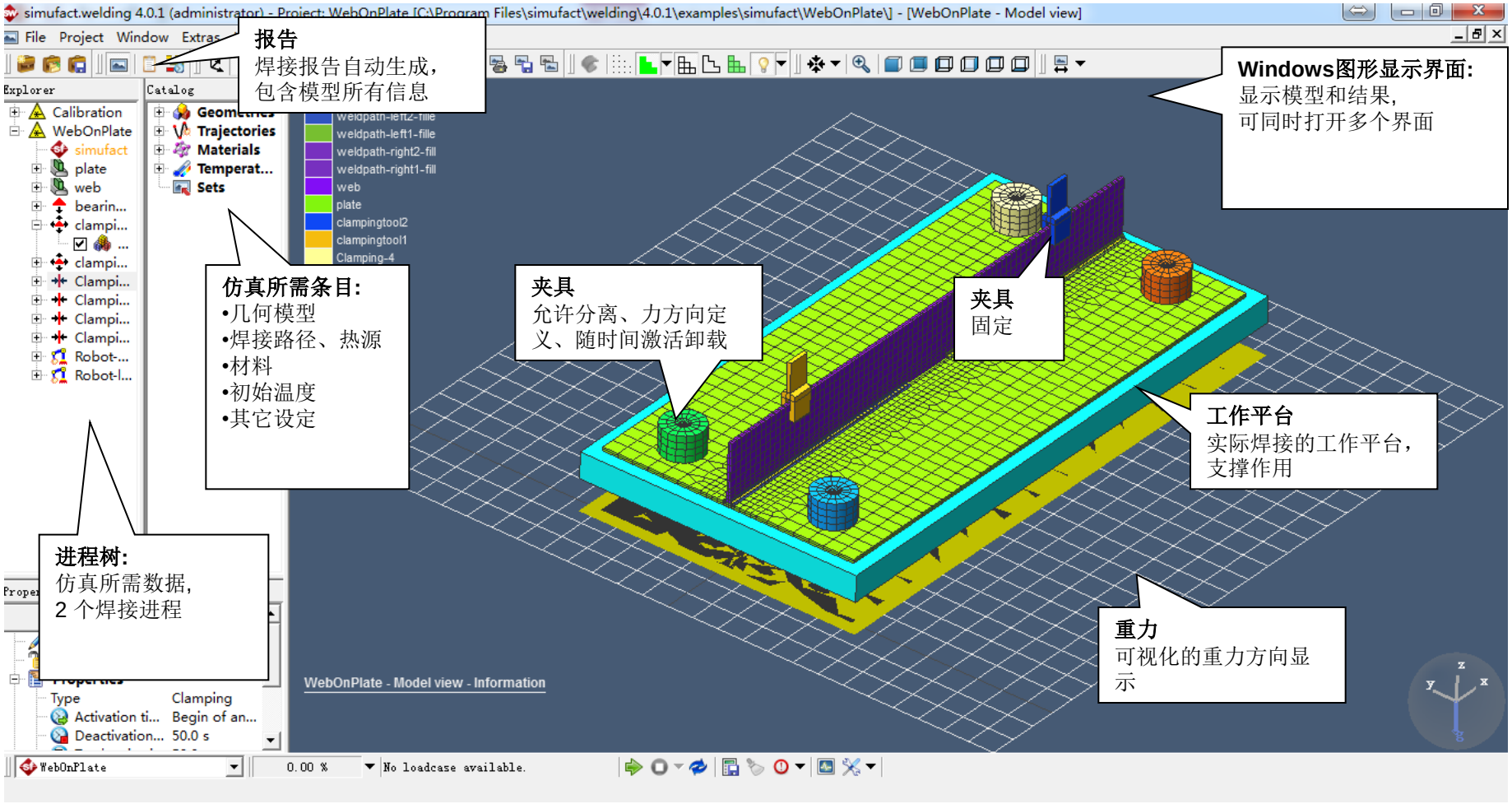
材料

微观结构
相变
硬度
裂纹

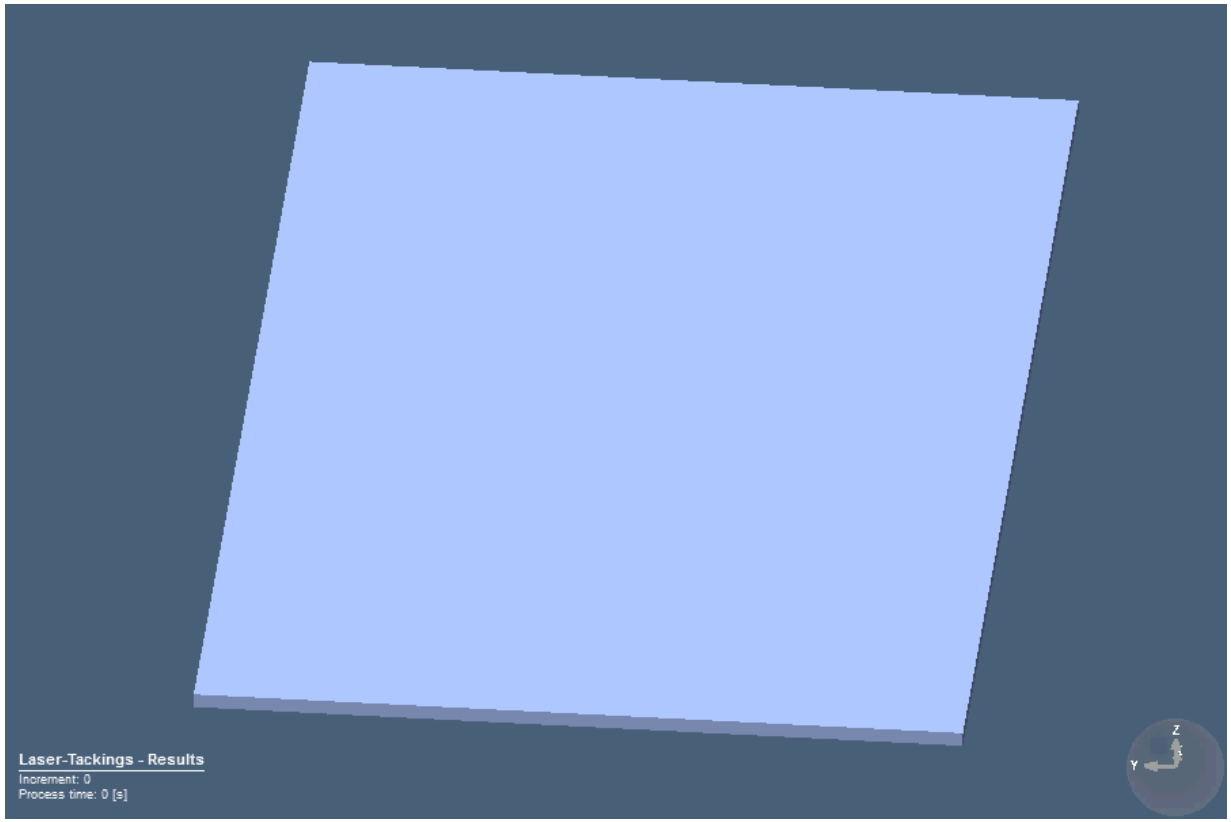


Simufact.welding

Simufact.welding 主界面



焊接工艺虚拟设计，包括：点焊固定、装夹位置以及焊前预热等。

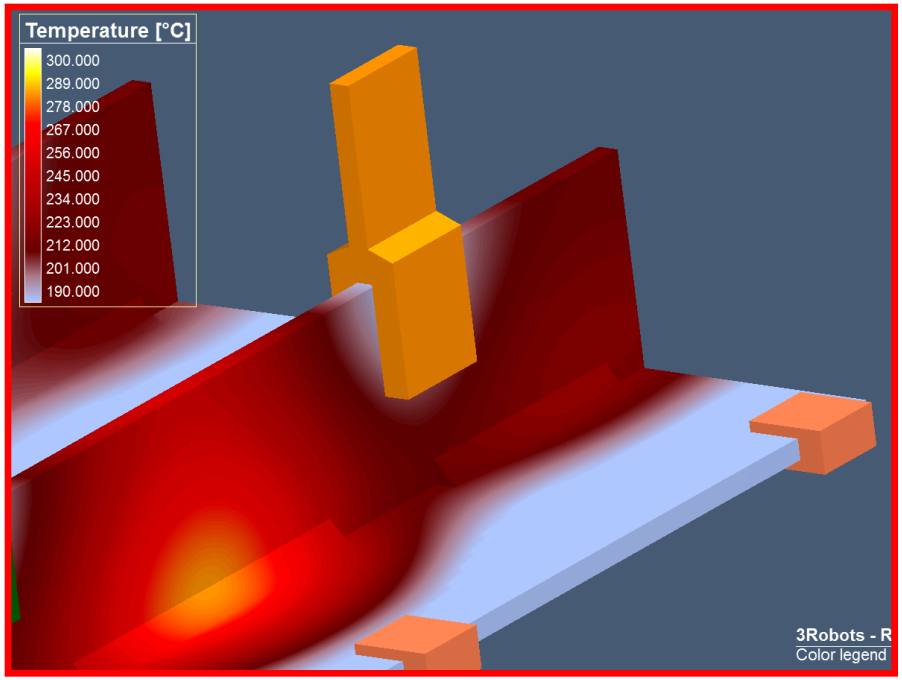


点焊固定：
焊件前端分离被抑制

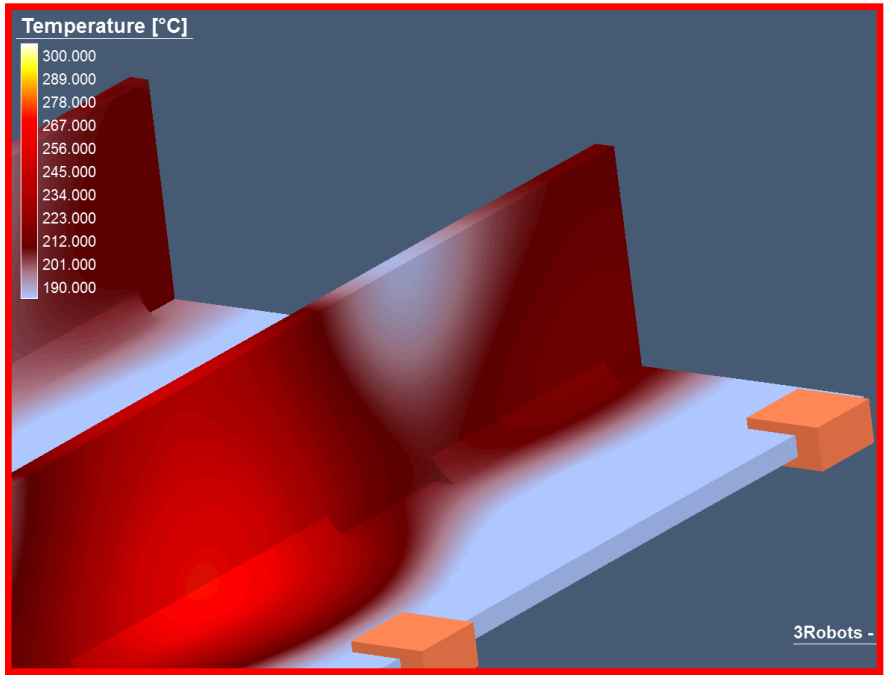
工件内部温度分布及与夹具的热交换

考虑与夹具热交换的影响

夹具松开前

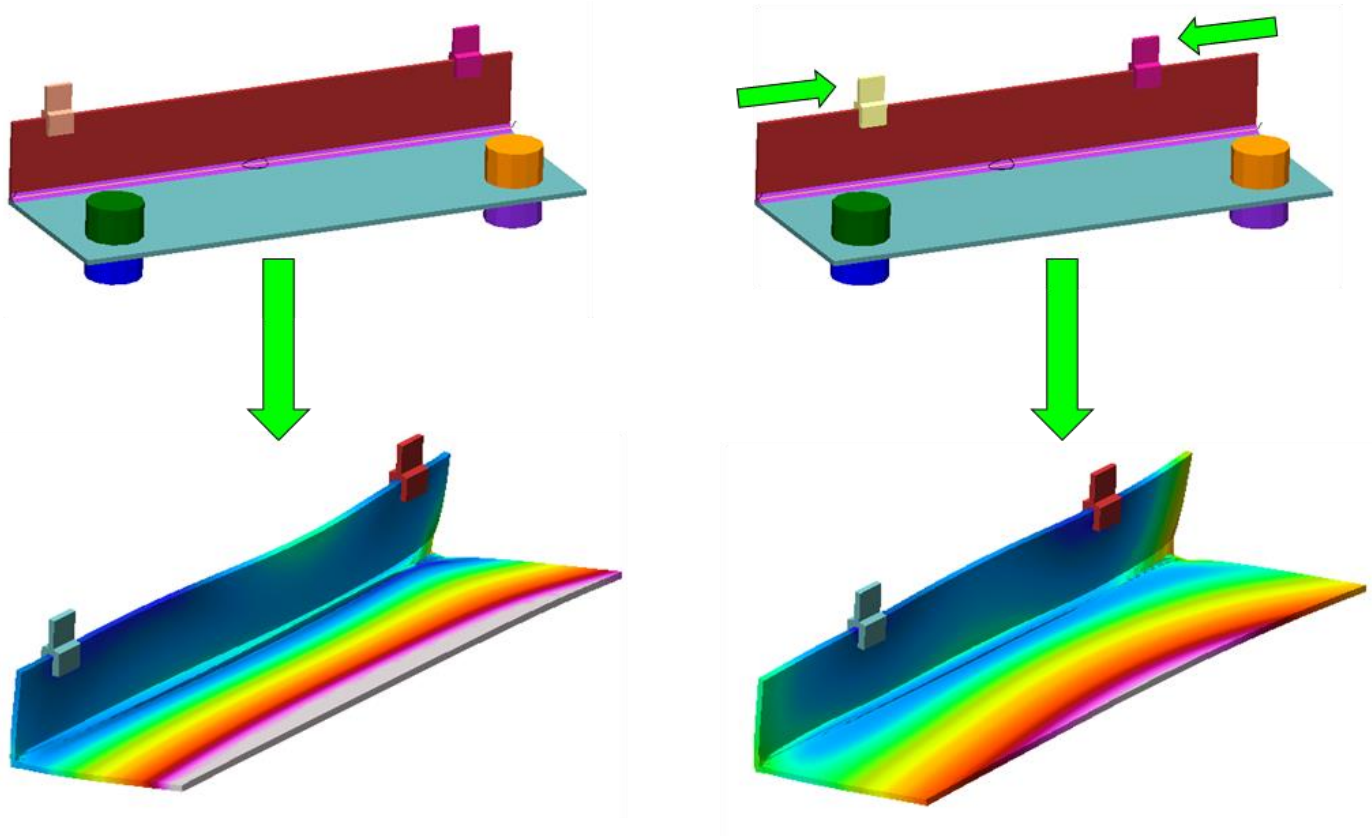


夹具松开后



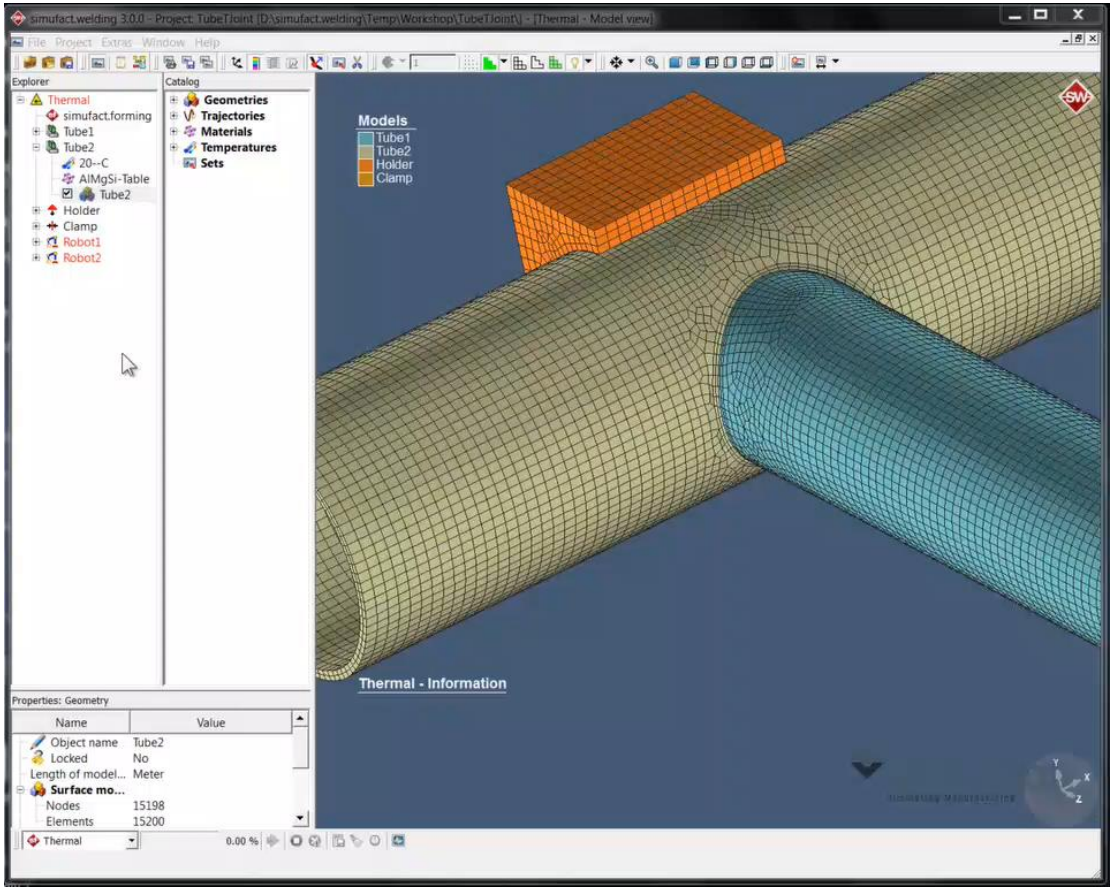
简单快捷的工艺仿真比较 (工艺复制)

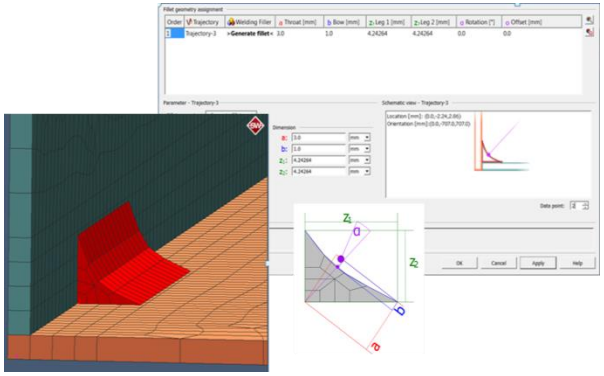
如：通过比较焊接变形，进行装夹位置优化。

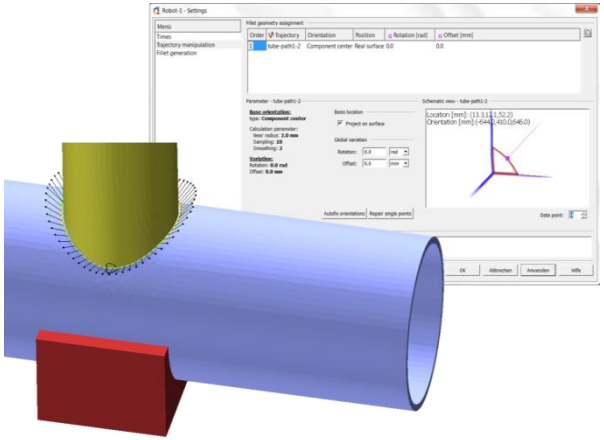


焊接路径与焊缝填充

- 通过选取节点或导入外部坐标文件(.CSV)，可以轻松进行焊接路径定义
- 对于角焊缝，支持自动生成焊缝填充模型及其单元网格

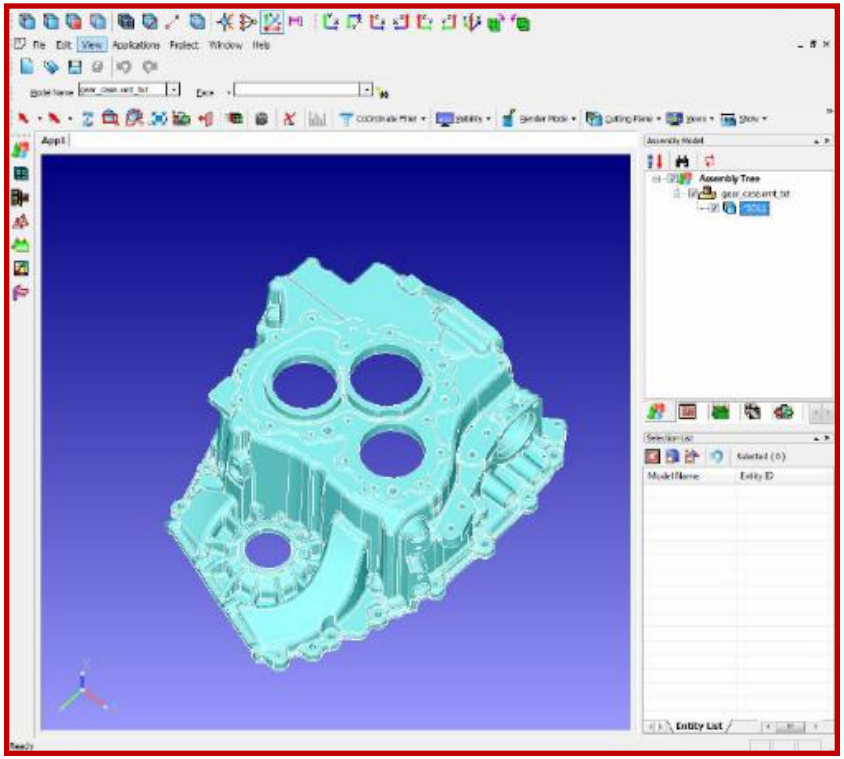


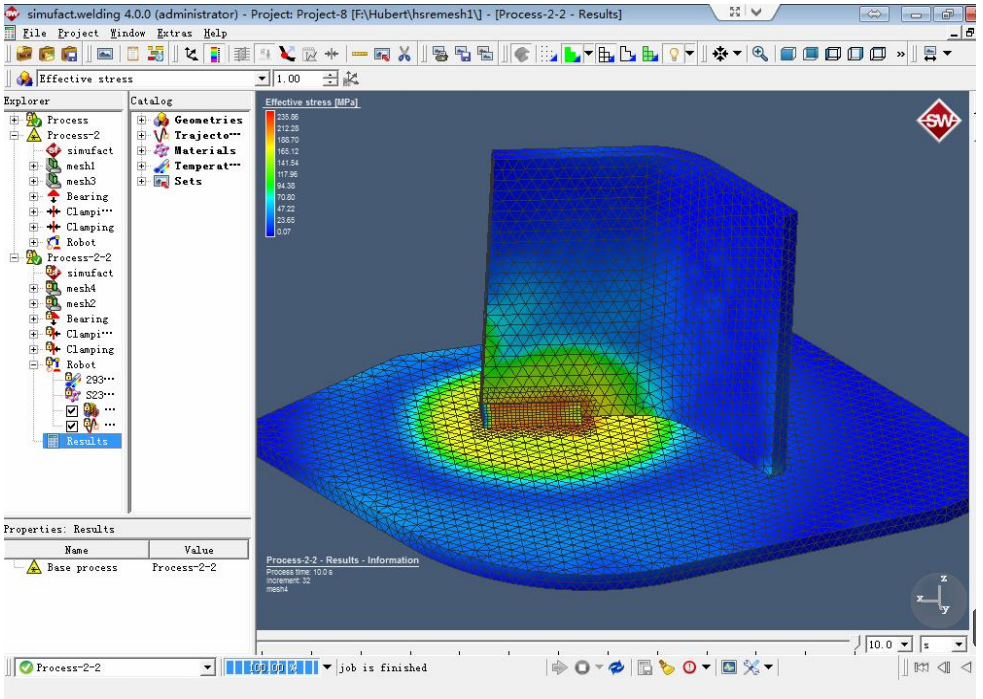




几何模型与网格

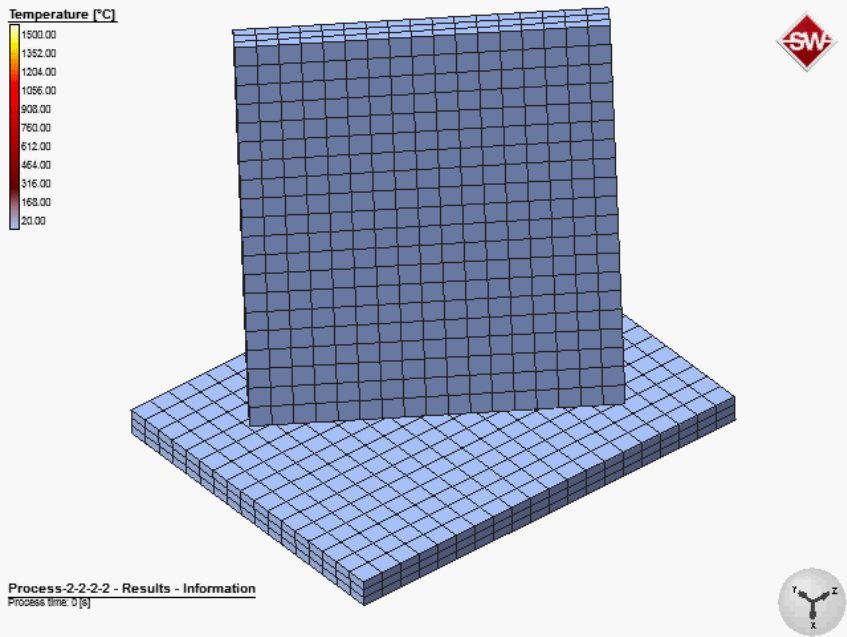
- 集成了专业的网格划分工具Simufact.mesh Simlab
- 对模型进行四面体、六面体网格划分，针对模型特征进行局部细化
- 支持四面体单元

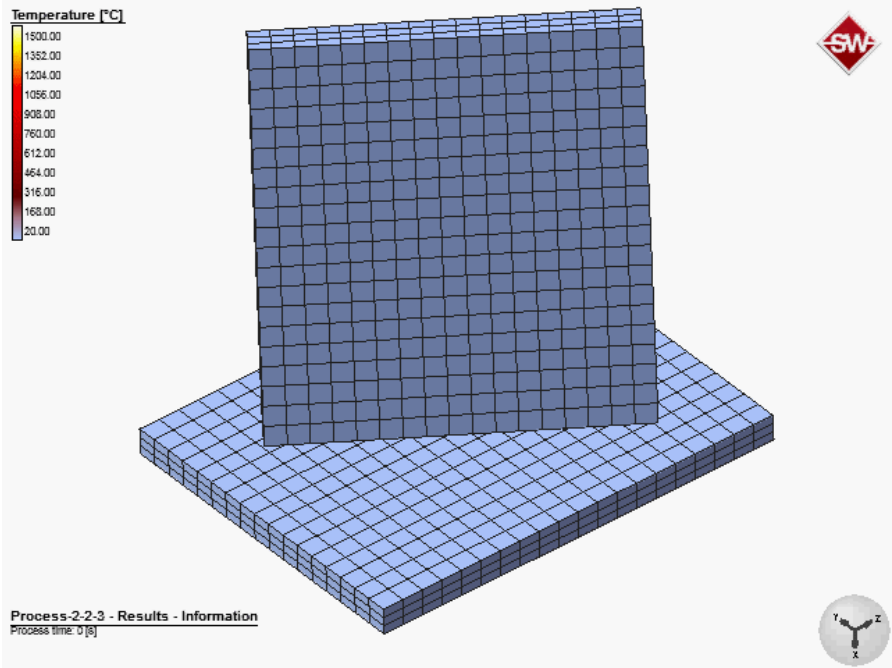




几何模型与网格

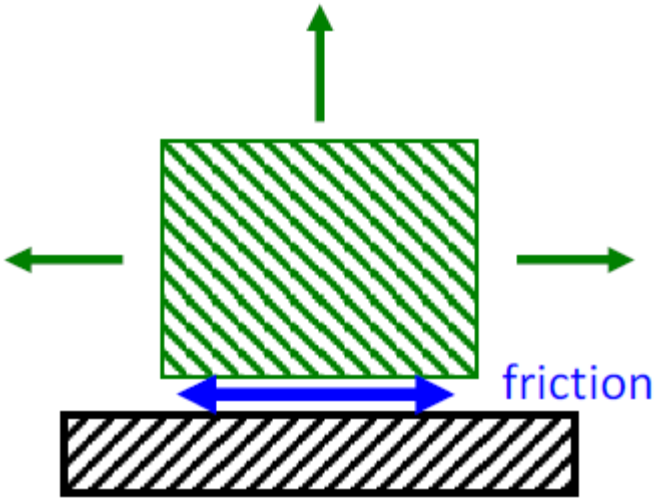
建模无需节点耦合
在计算过程中，对焊缝周围区域网格单元进行自动细化与粗化

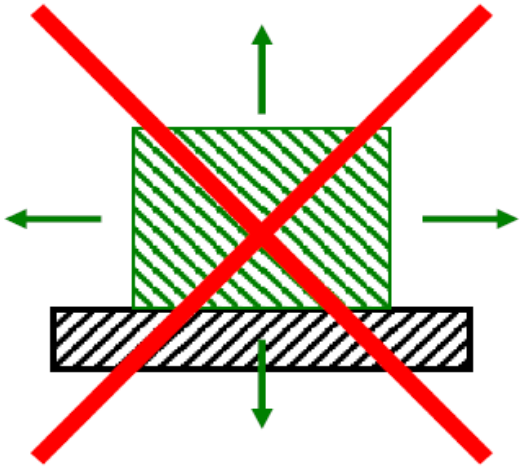


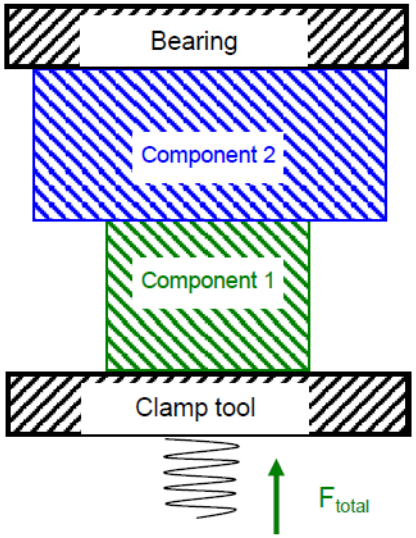


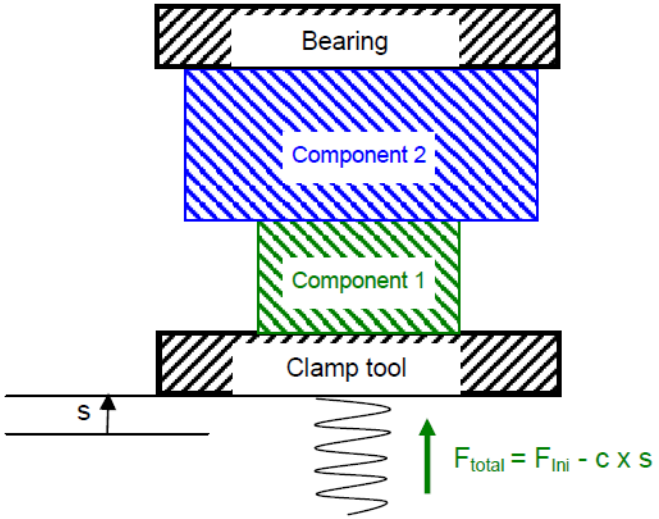
力边界条件

- 支撑台
- 固定
- 夹具



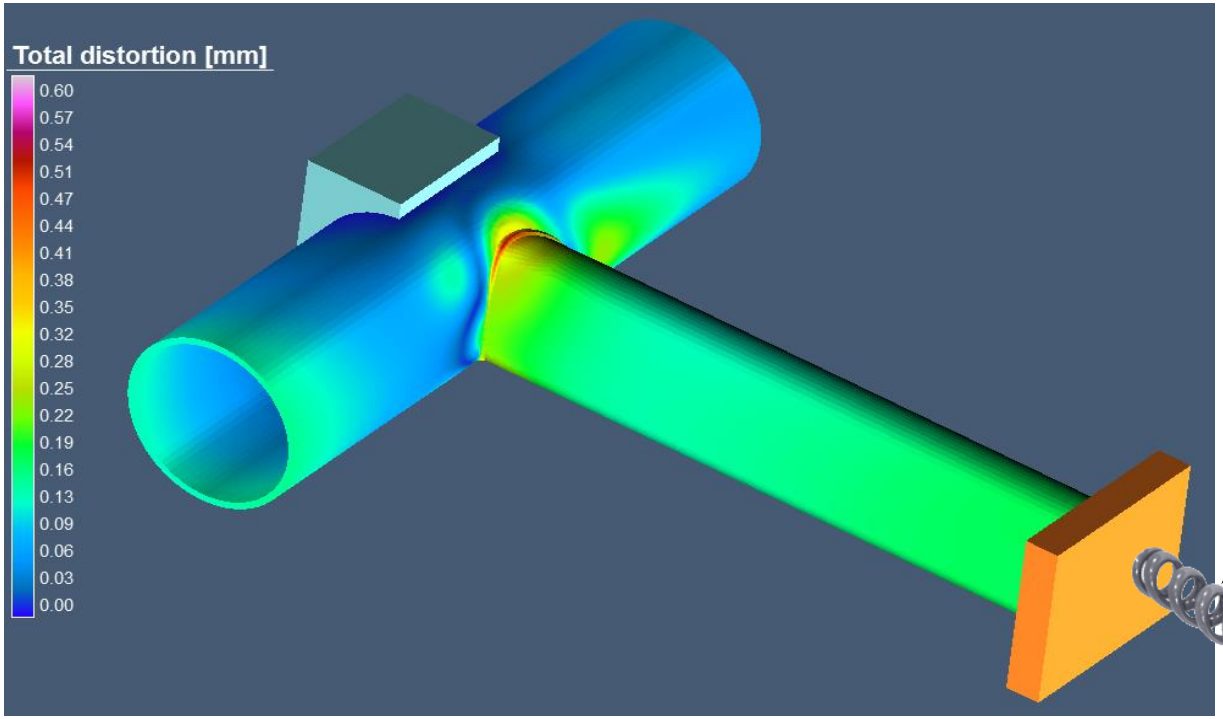






力边界条件

- 支持 自动生成/外部导入 装夹几何模型
- 灵活控制夹具的作用力与时间



弹簧刚度C:

自动根据接触面的方向确定方向

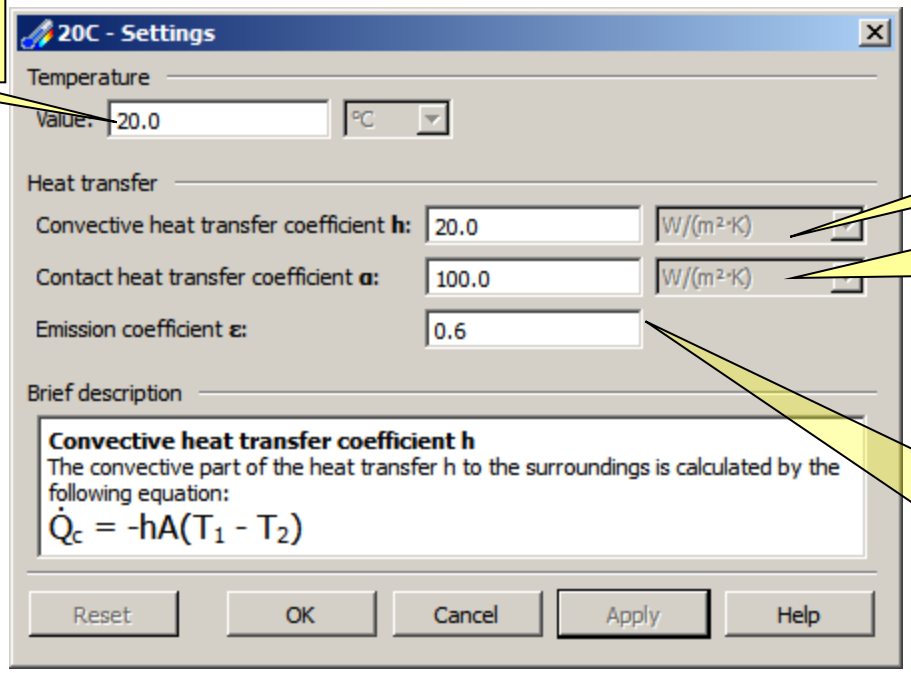
施加力F:

自动根据接触面的方向确定方向

热边界条件

- 自动检测符合热交换条件的面
- 接触面热交换通过热流定义
- 对于不同的工件可定义不同的预热温度
- 预设定参数默认值

工件初始温度



对流：

$$Q_c = -h\,A\,(T_1 - T_2)$$

面接触热传导系数：

$$Q_{CHT} = \alpha\,A\,(T_1 - T_2)$$

辐射换热系数 ε:

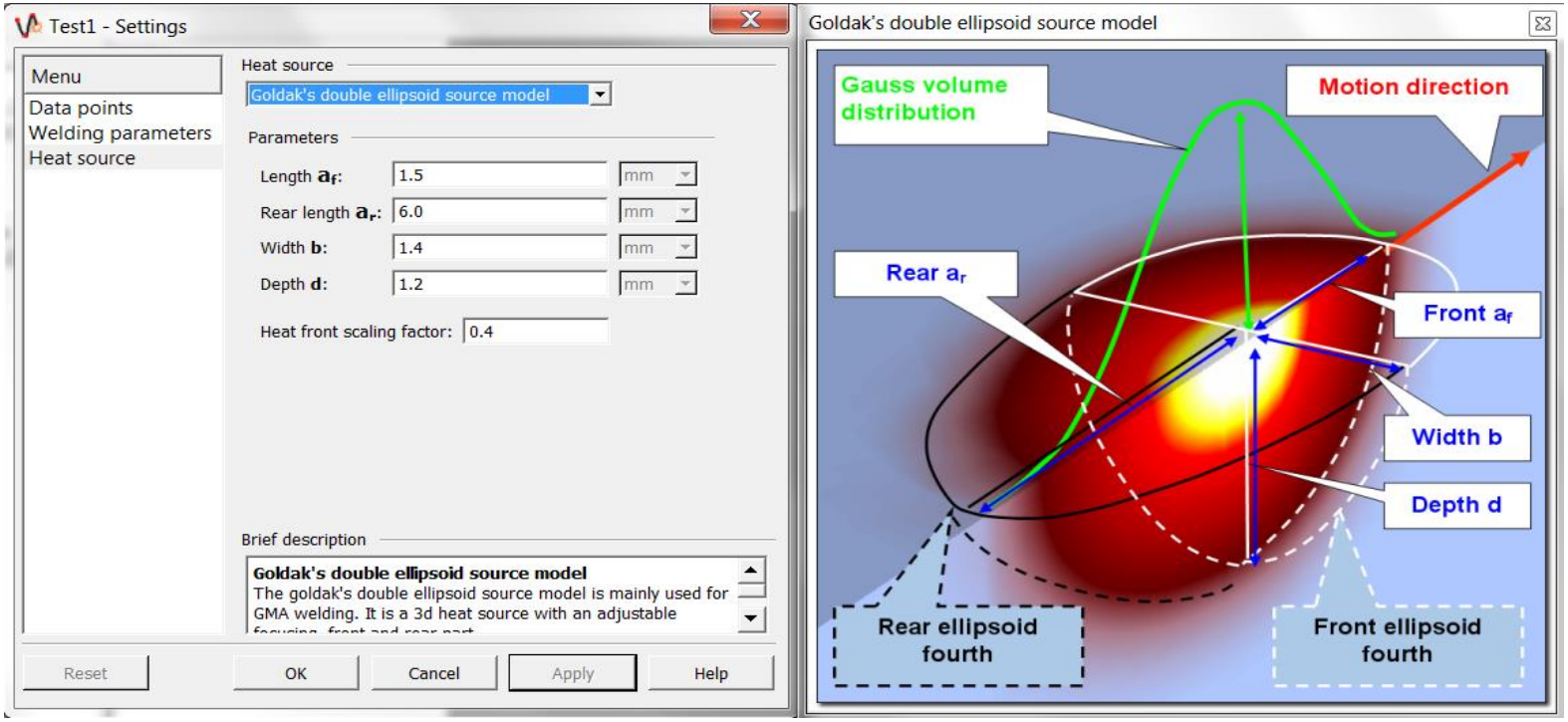
Stefan-Boltzmann方程：

$$Q_E = -\varepsilon\,A\,(T_1^4 - T_2^4)$$

$(0 \le \varepsilon \le 1)$

热源模型

- 焊接结构计算中的热源模型是通过数学模型近似定义的。
- 对于传统低热流密度的焊接方法（如**SMAW, GMAW**等）可采用双椭球热源模型。
- 对于高能束焊接方法（如**EBW, LBW**等）可采用圆柱体热源模型（面体组合）。
- 热源模型可以组合使用，需要进行必要的热源校核。



热源模型

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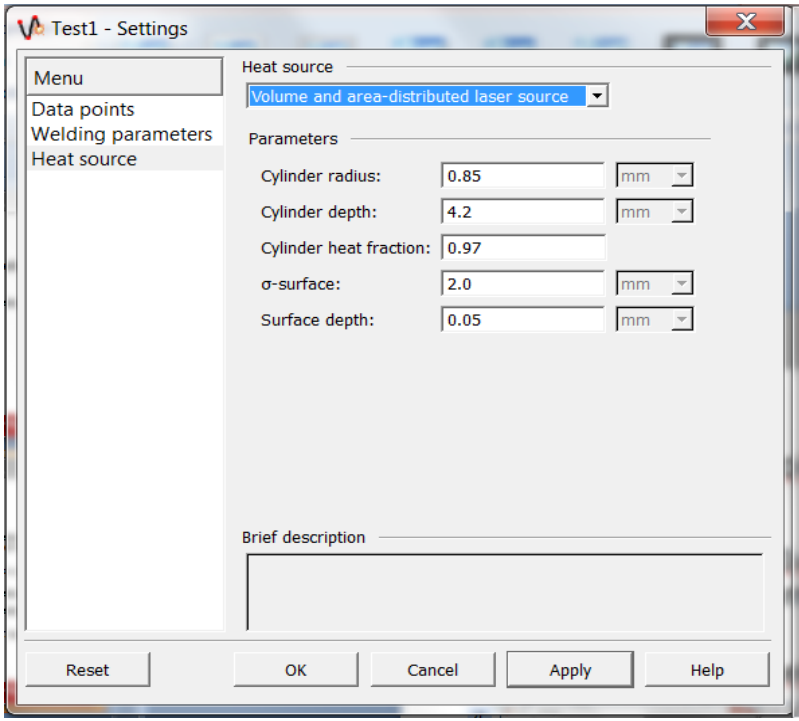
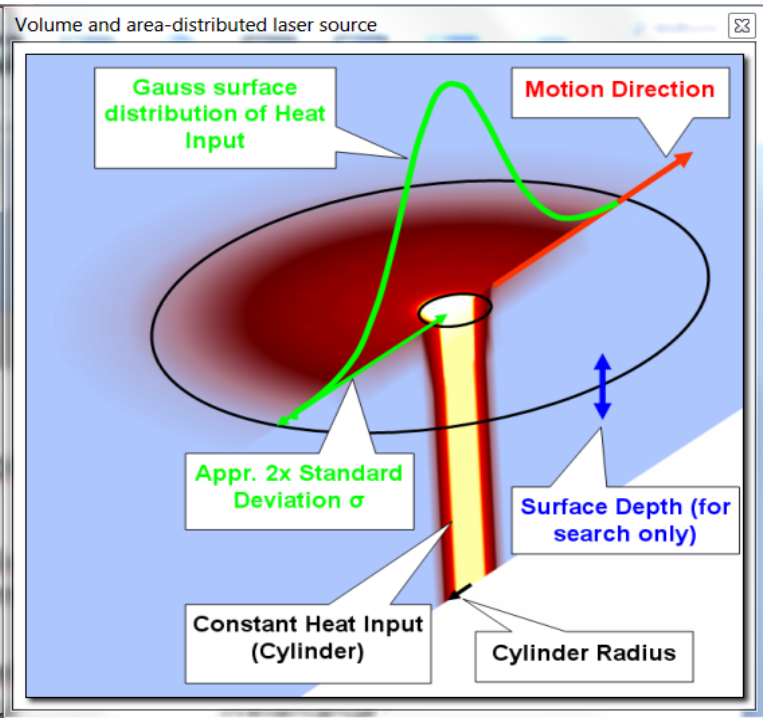
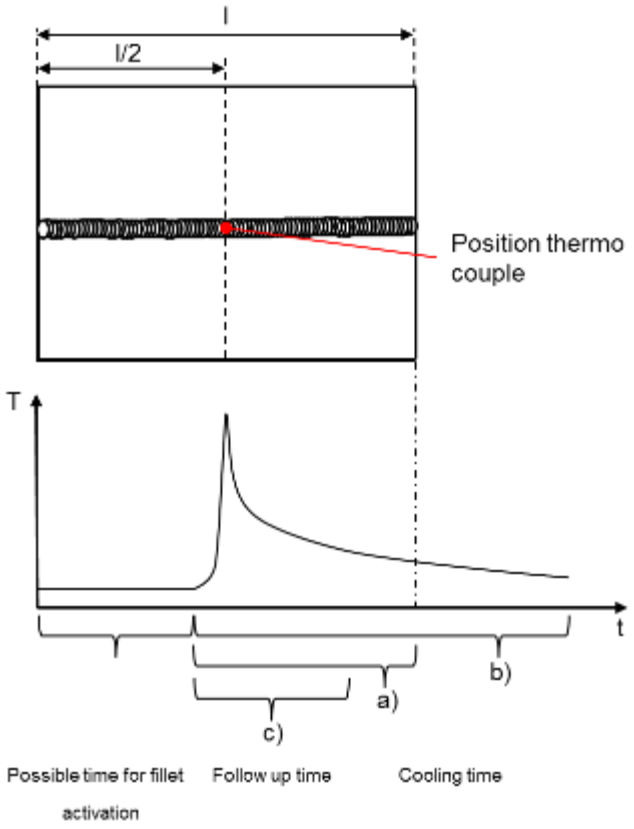
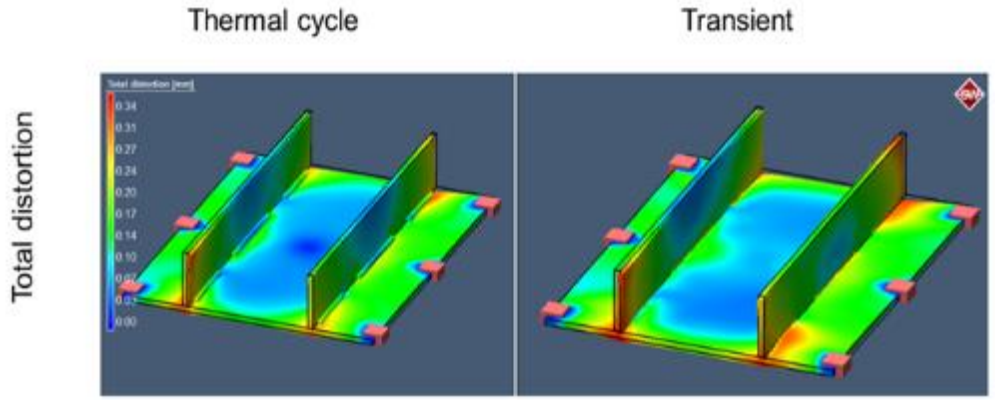




求解-热循环方法（Thermal Cycle /Meta-transient)

- 假设焊缝中点的温度曲线可以应用到整条焊缝上，由此来预测变形和残余应力
- 快速寻找优化方案





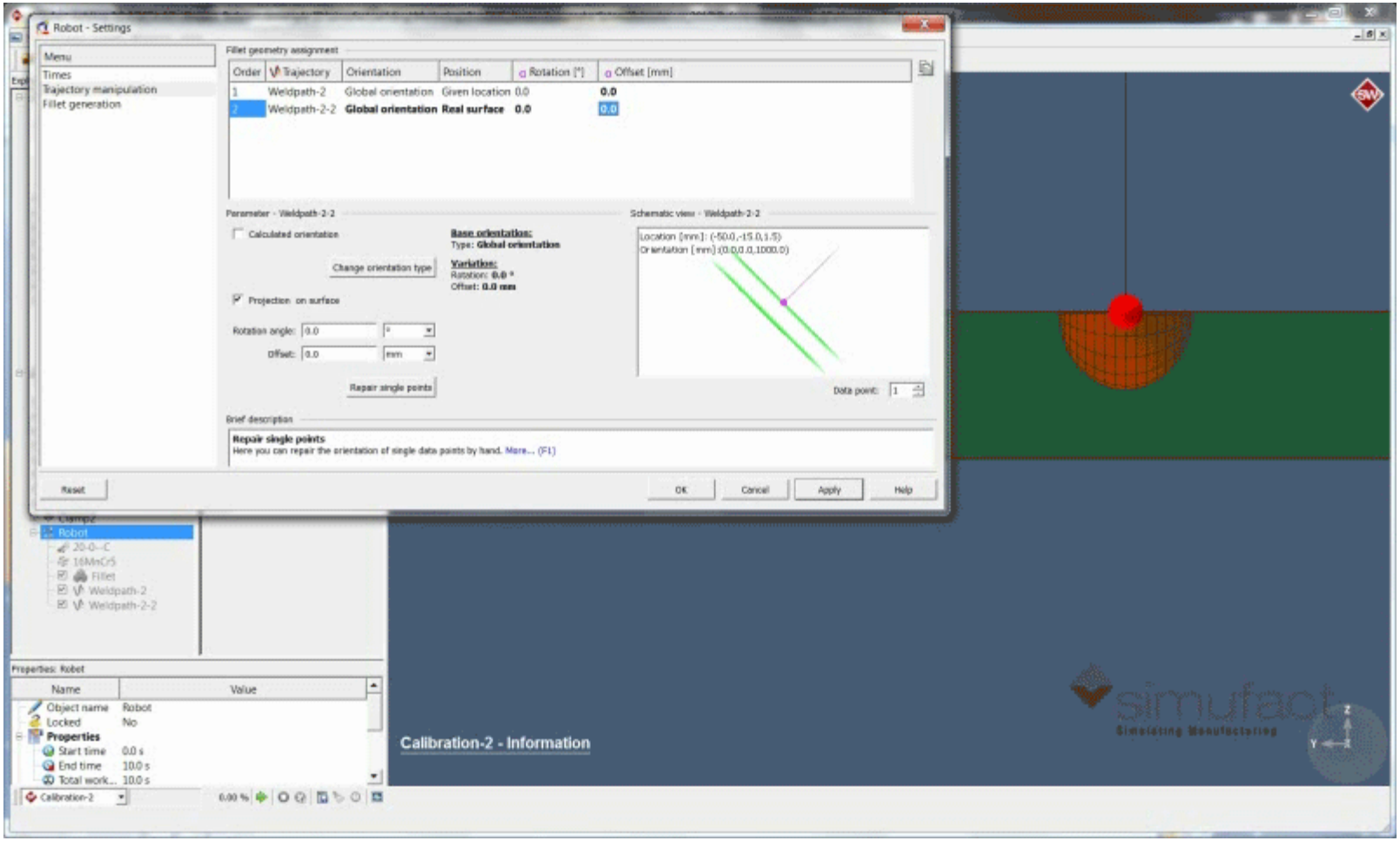
	Thermal cycle	Transient
Wall time	9484.29	38247.76
Computation time	~3h	~14h

→ **Speed up of 4.6**

增速4.6倍

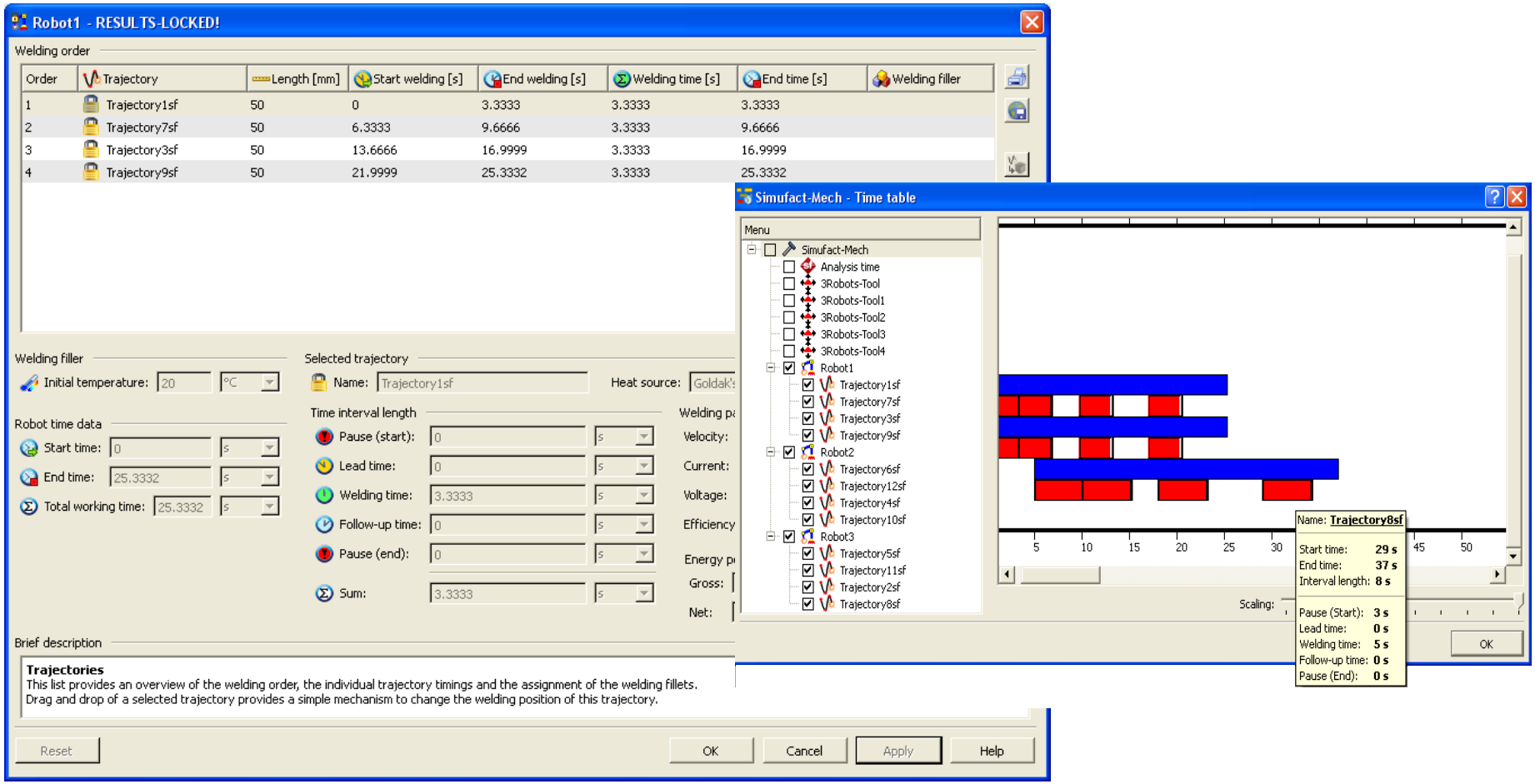
热源模型

- 利用热源定位功能设置组合热源



时间管理

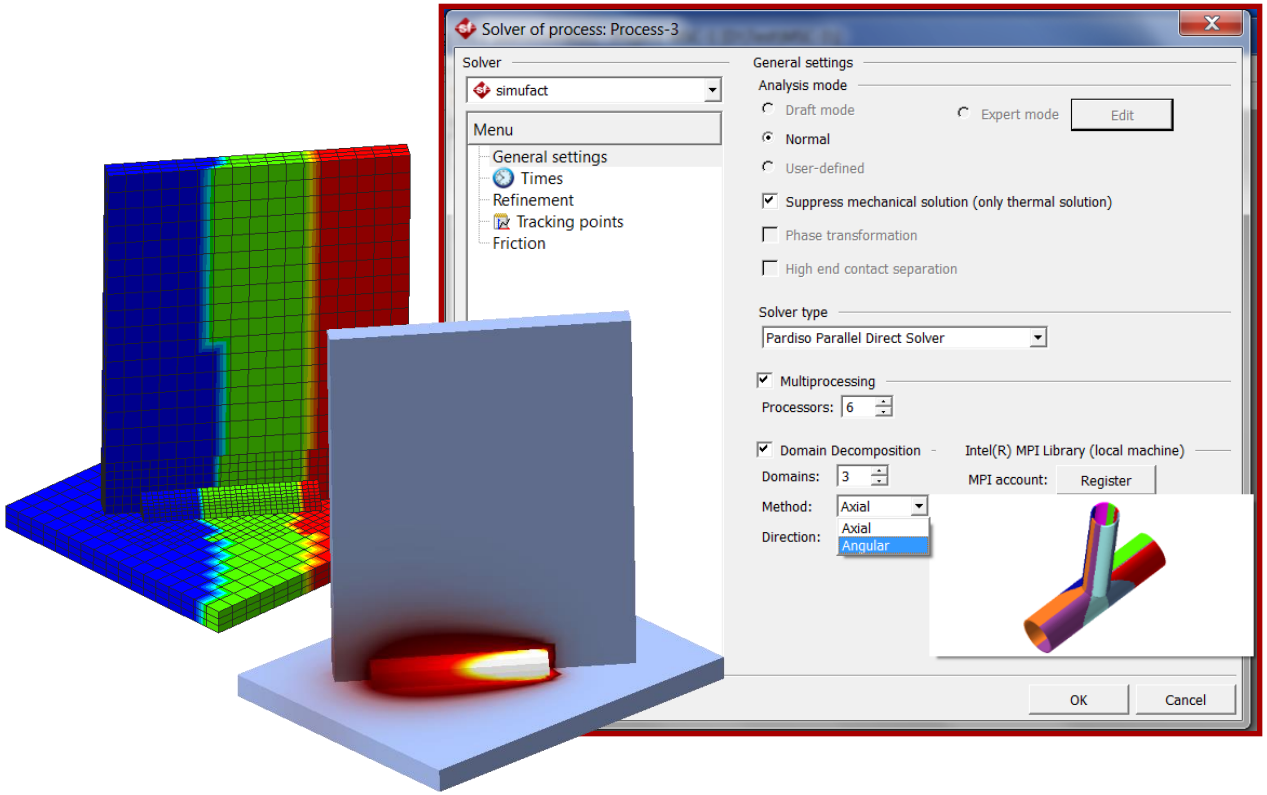
- Simufact.welding 支持定义多个机械手（焊枪），一个机械手支持定义多条焊接路径。
- 焊接路径、装夹的作用时间以及求解器的计算时间可以灵活管理，也可在时间表中直观地显示。



求解-DDM

优化了内存管理与计算时间，为缩短计算时间新增功能：

- 区域分解方法 (DDM)

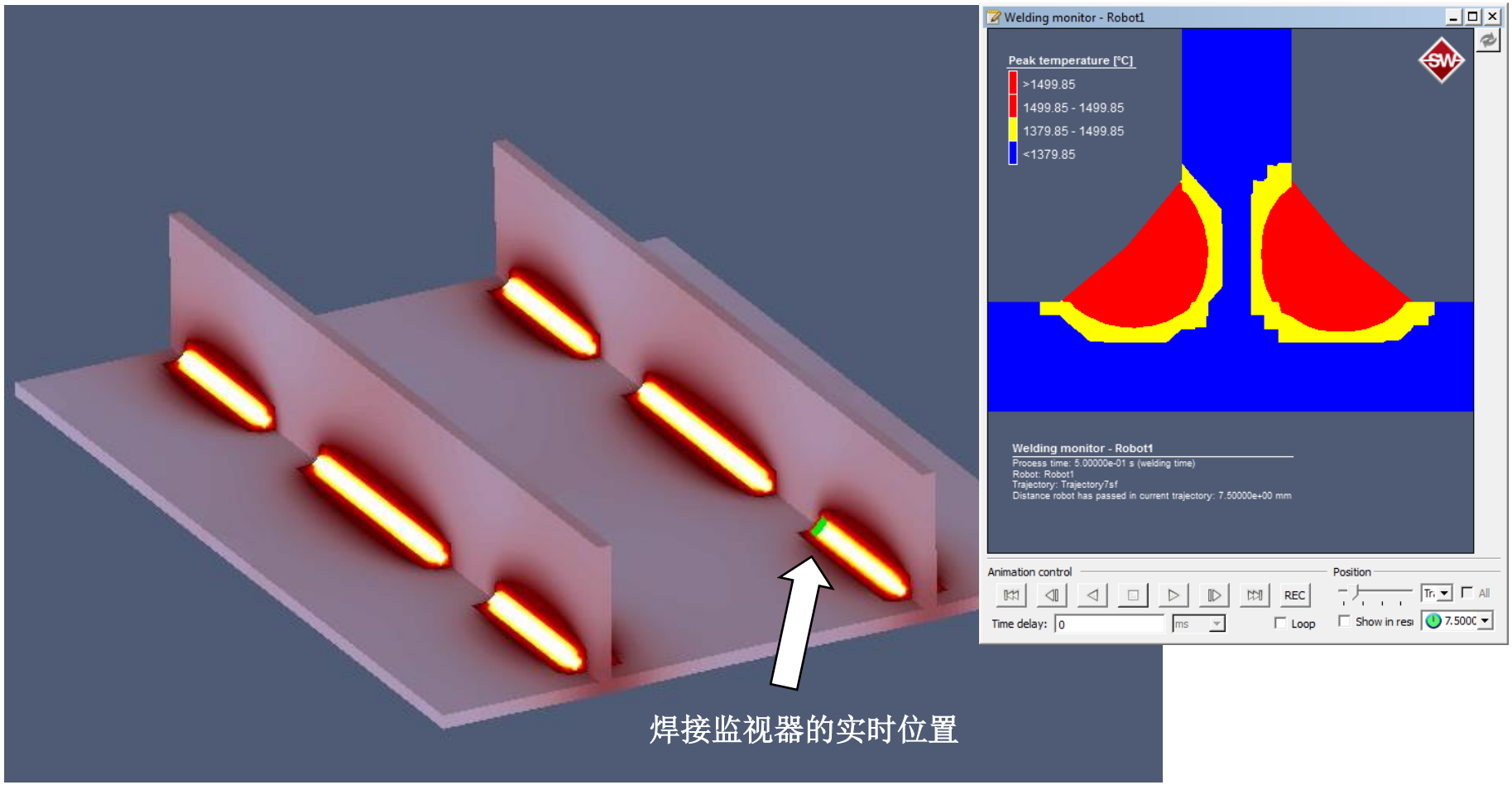


通过将整体区域划分为多个小区域并行计算，各个小区域之间的数据能够被及时整合。可配合多核并行进一步缩短计算时间。

通过DDM功能，Simufact.welding能够实现大规模构件的焊接仿真。

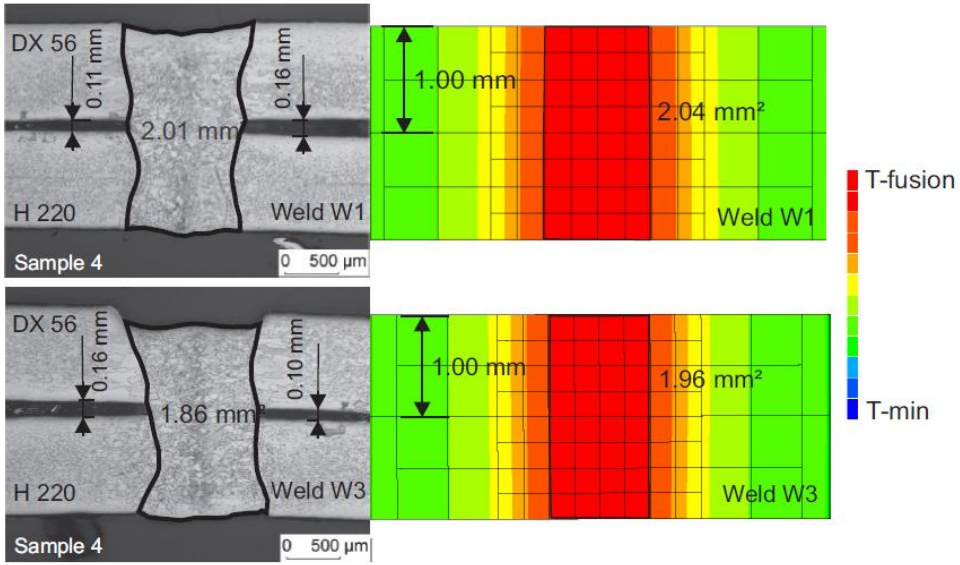
后处理-焊接监视器

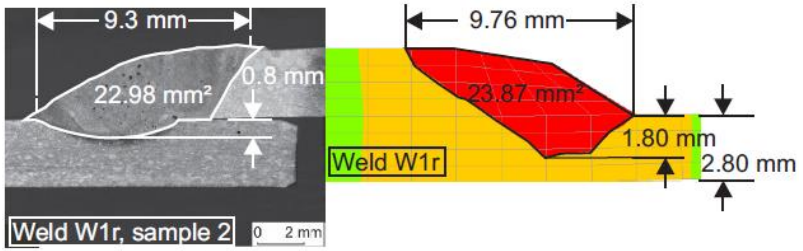
焊接监视器与焊接机器人（焊枪）一起运动

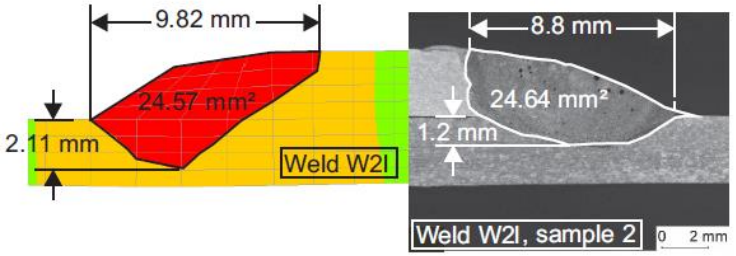


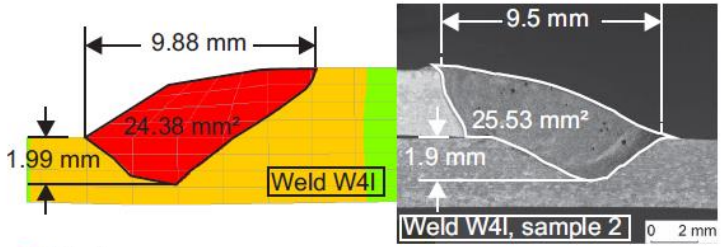
后处理-焊接监视器

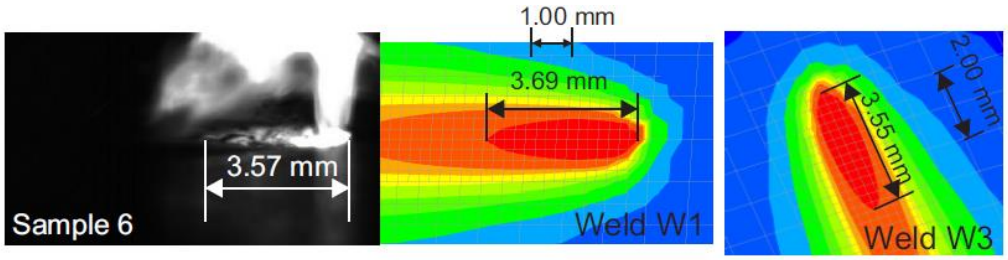
对比实际结果校正热源模型







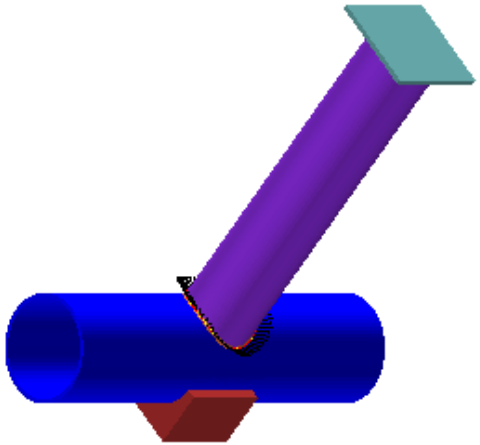




后处理-计算报告

Process report

(Simufact.welding 3.1.0.14922.x86 (Windows) - 2013/5/8 15:36:31)



Process: TubeT-Joint

Comment:
Simufact.welding user example with simufact solver rev. 2284:
User example TubeT-Joint: two aluminium (Al99,5) tubes welded by a robot with T-Joint.
(c) Simufact.welding 3.1 (08/2012)

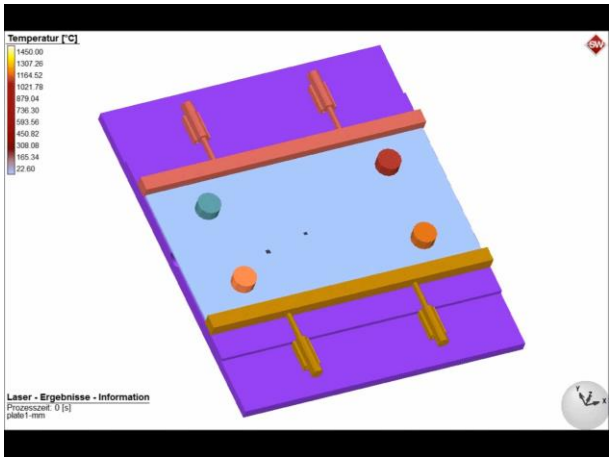
- 计算项目属性（组件、边界条件、焊接路径、焊枪等）
- 焊接路径作用时间表
- 焊接参数与热源模型参数
- 求解器（类型、时间、网格细化与时间步等）
- 材料（标准、牌号）

支持输出为.html格式

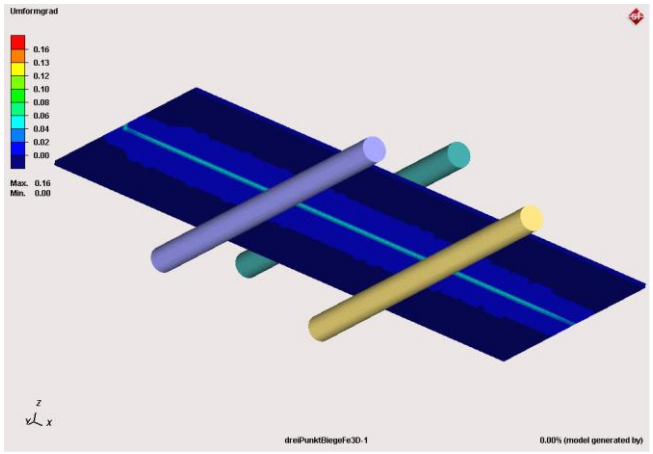
工艺链模拟-三点弯曲试验

工艺链焊接 - 成形/塑性应变作为材料损伤指标

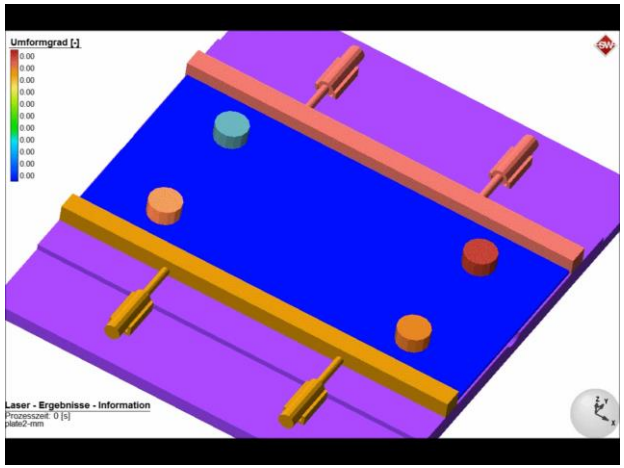
焊接中温度分布

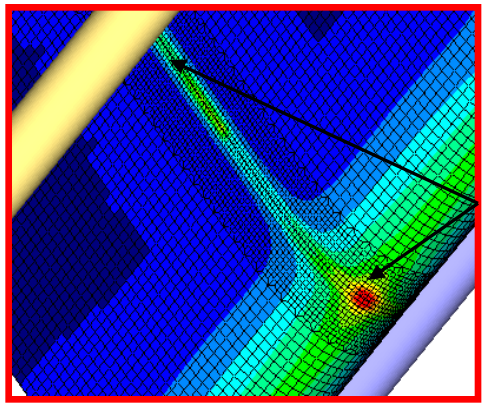


成形中应变分布



焊接中应变分布



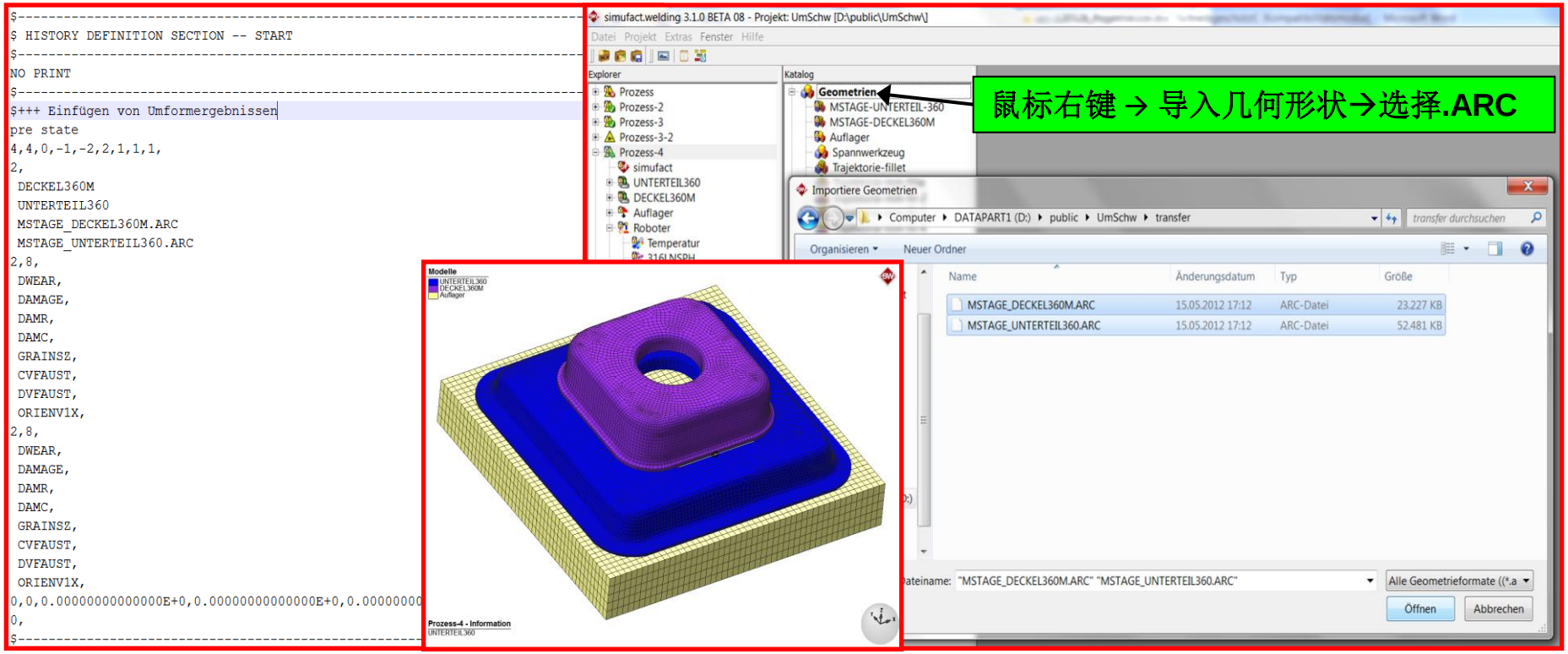


最大塑性应变出现在焊缝与成形模具接触处

工艺链模拟-深冲与焊接

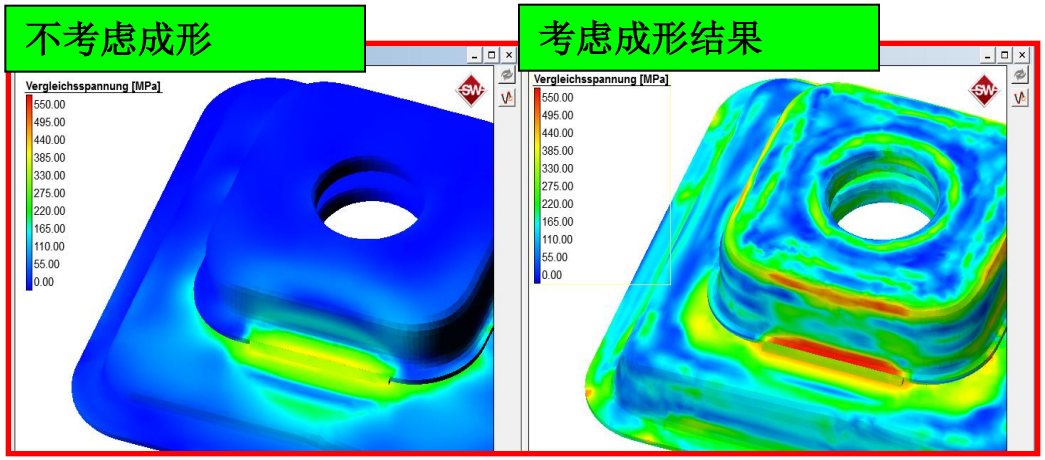
在焊接分析中考虑焊前塑性应变和残余应力

- 焊接前模具分离（Release），冷却（Cooling），切削（Trimming）和定位（Positioning）可在Simufact.Forming中实现
- 成形后的计算结果通过.ARC文件导入到Simufact.welding进行焊接模拟计算

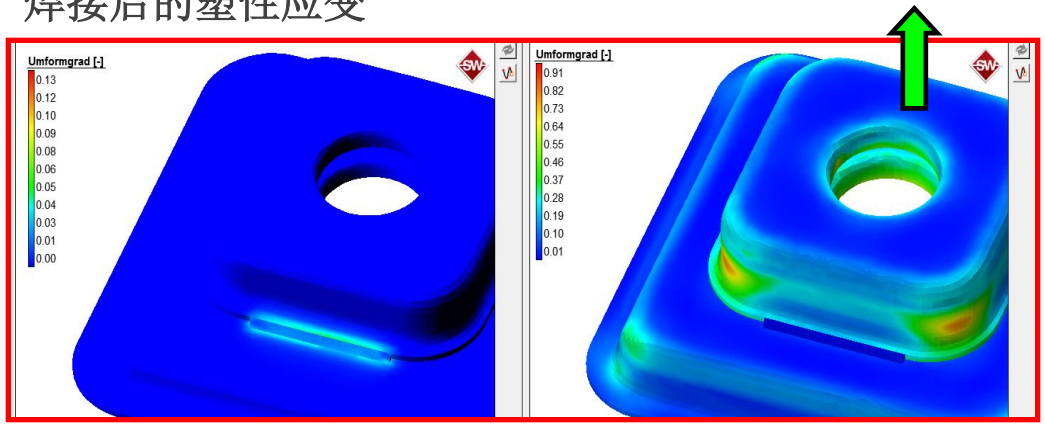


工艺链模拟-深冲与焊接

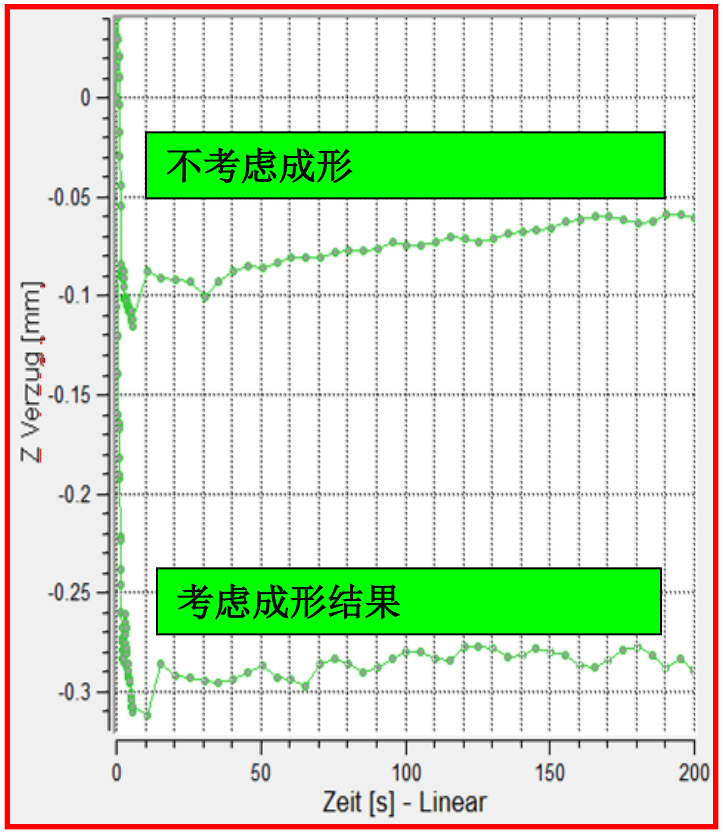
焊接后的残余应力



焊接后的塑性应变



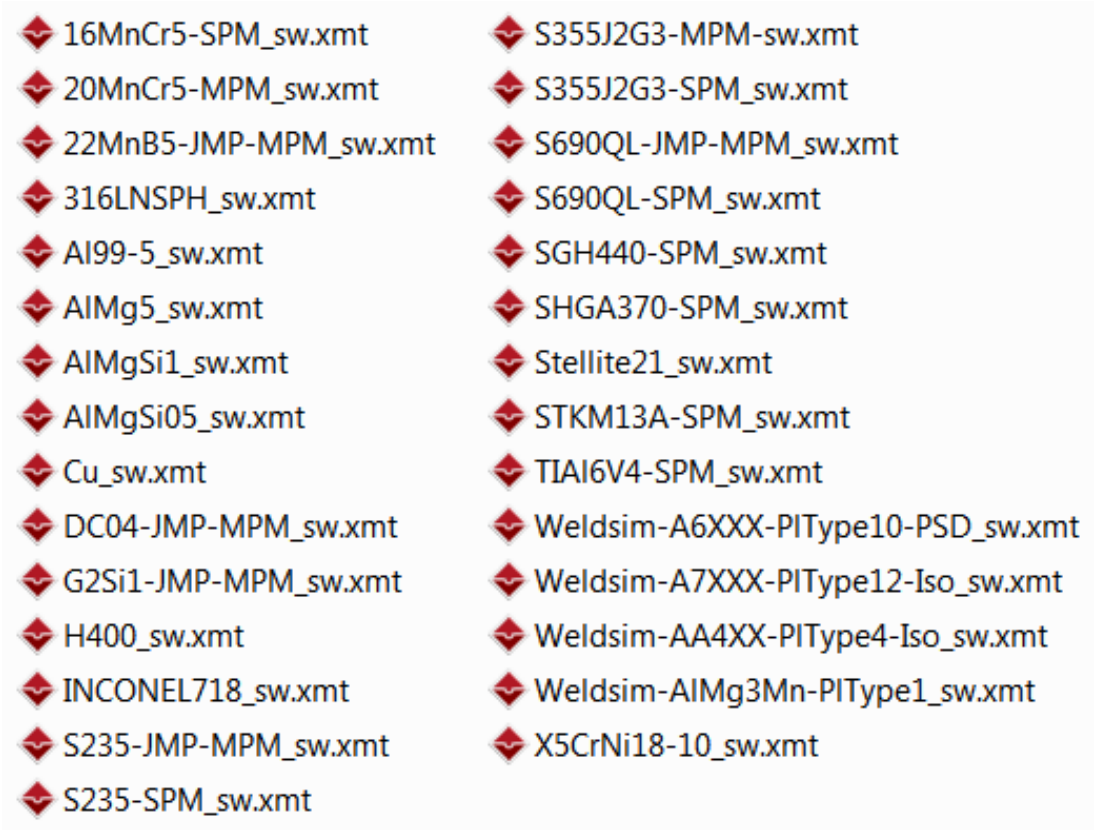
扭曲比较



- 焊接前工件的塑性应变和残余应力将影响工件焊接的整体应力分布与变形

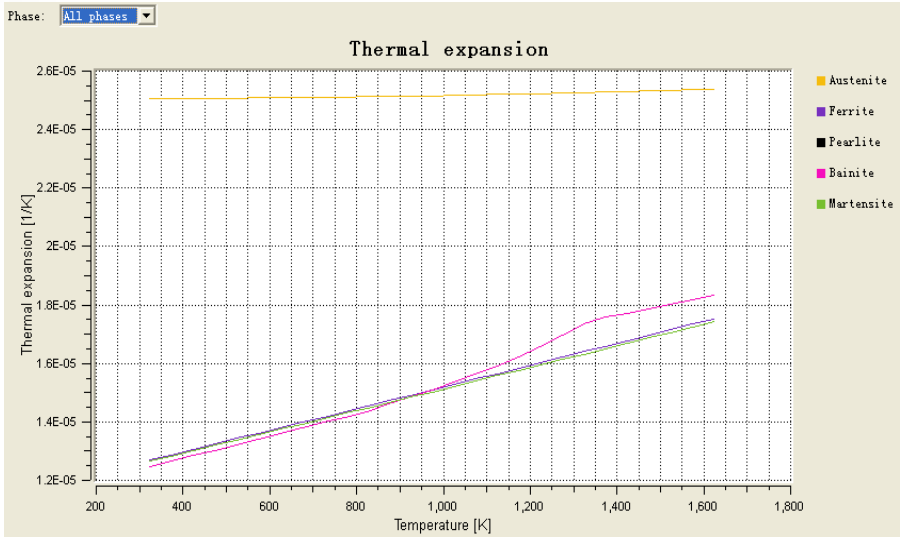
材料

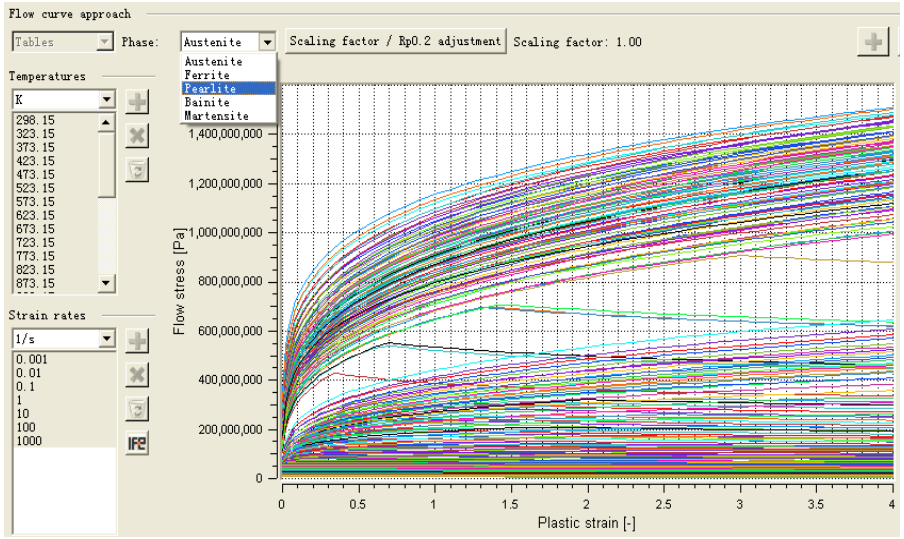
- 丰富的材料数据库
- 支持JMatPro直接接口



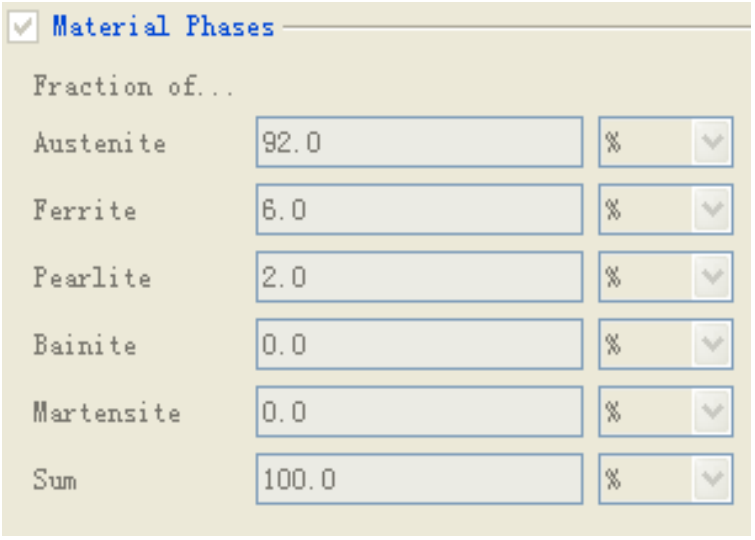
材料

●考虑不同相的混合材料属性

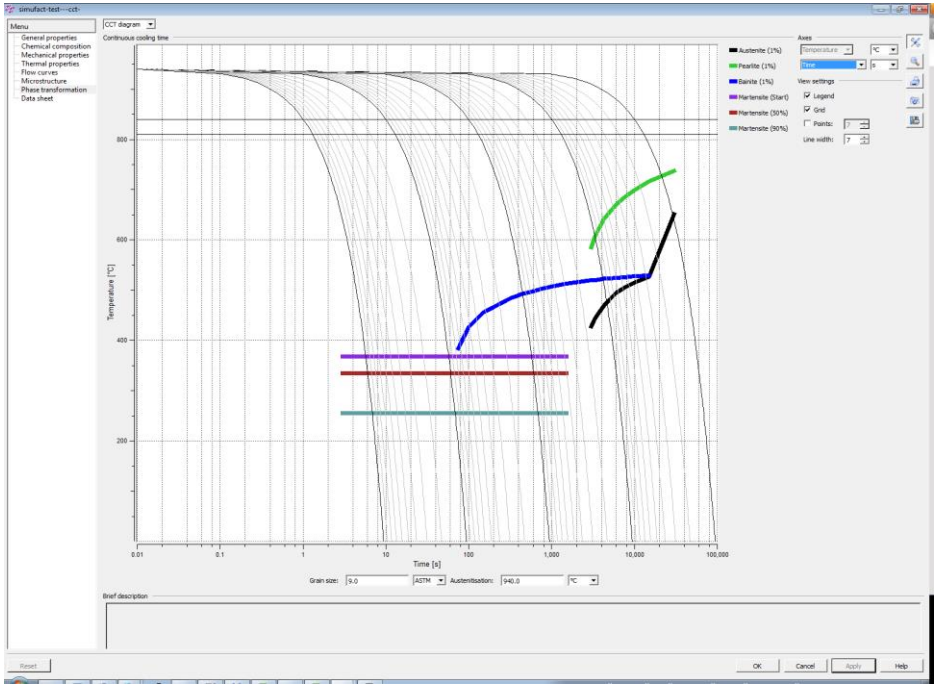


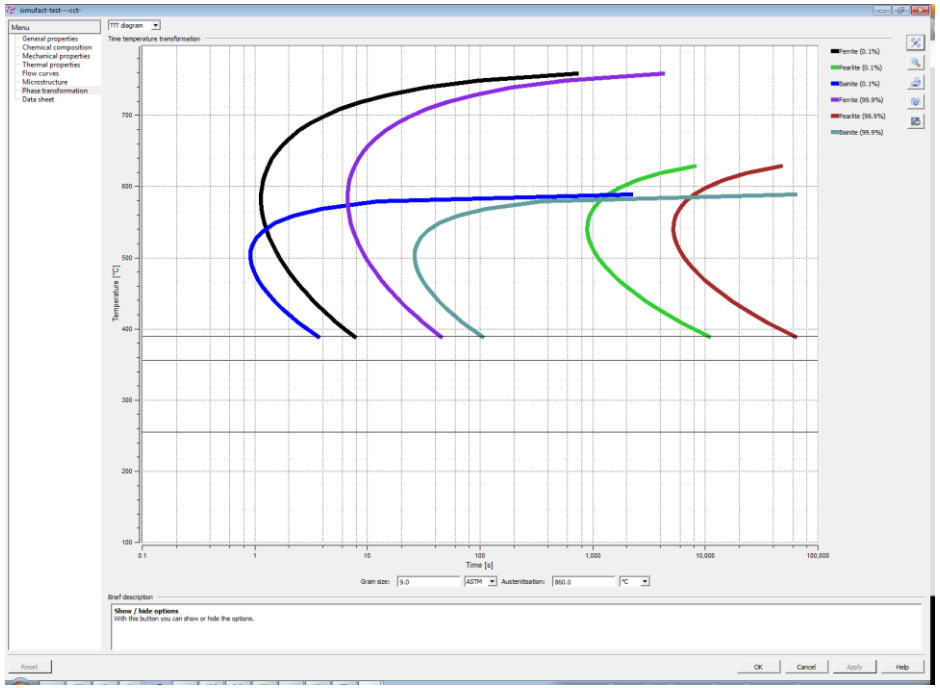


●设置材料初始相成份含量百分比



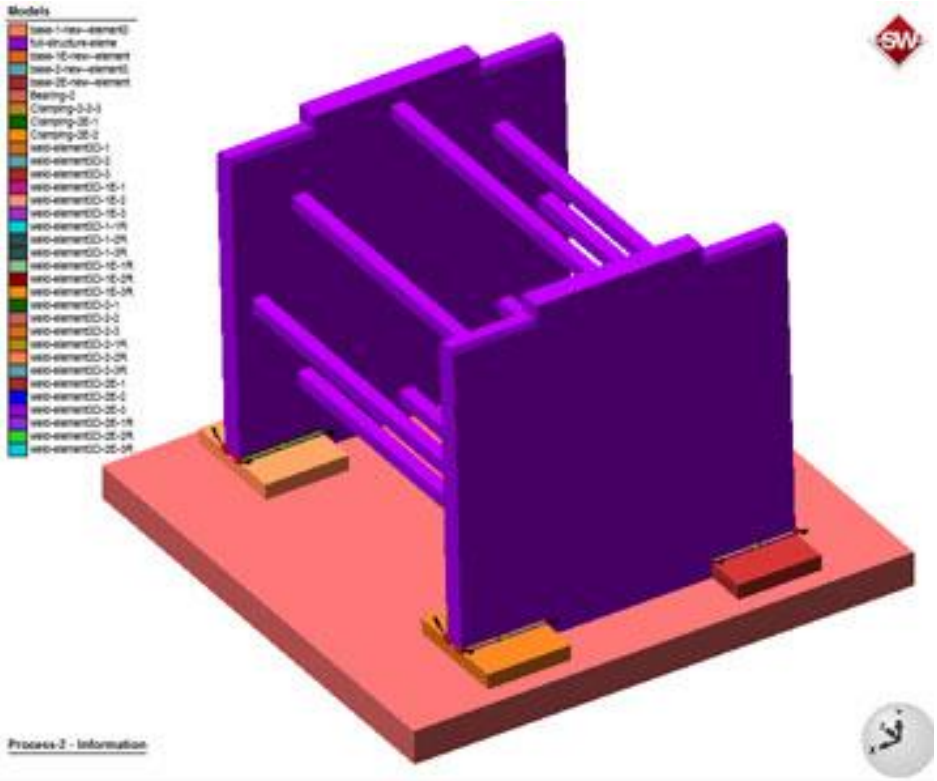
- 相变（Phase transformation）：
  - 连续相变（CCT）和等温相变（TTT）曲线（JMatPro）
  - 奥氏体向各相转变的数据：体积变化/潜热/TRIP效应
  - 准确计算变形和残余应力



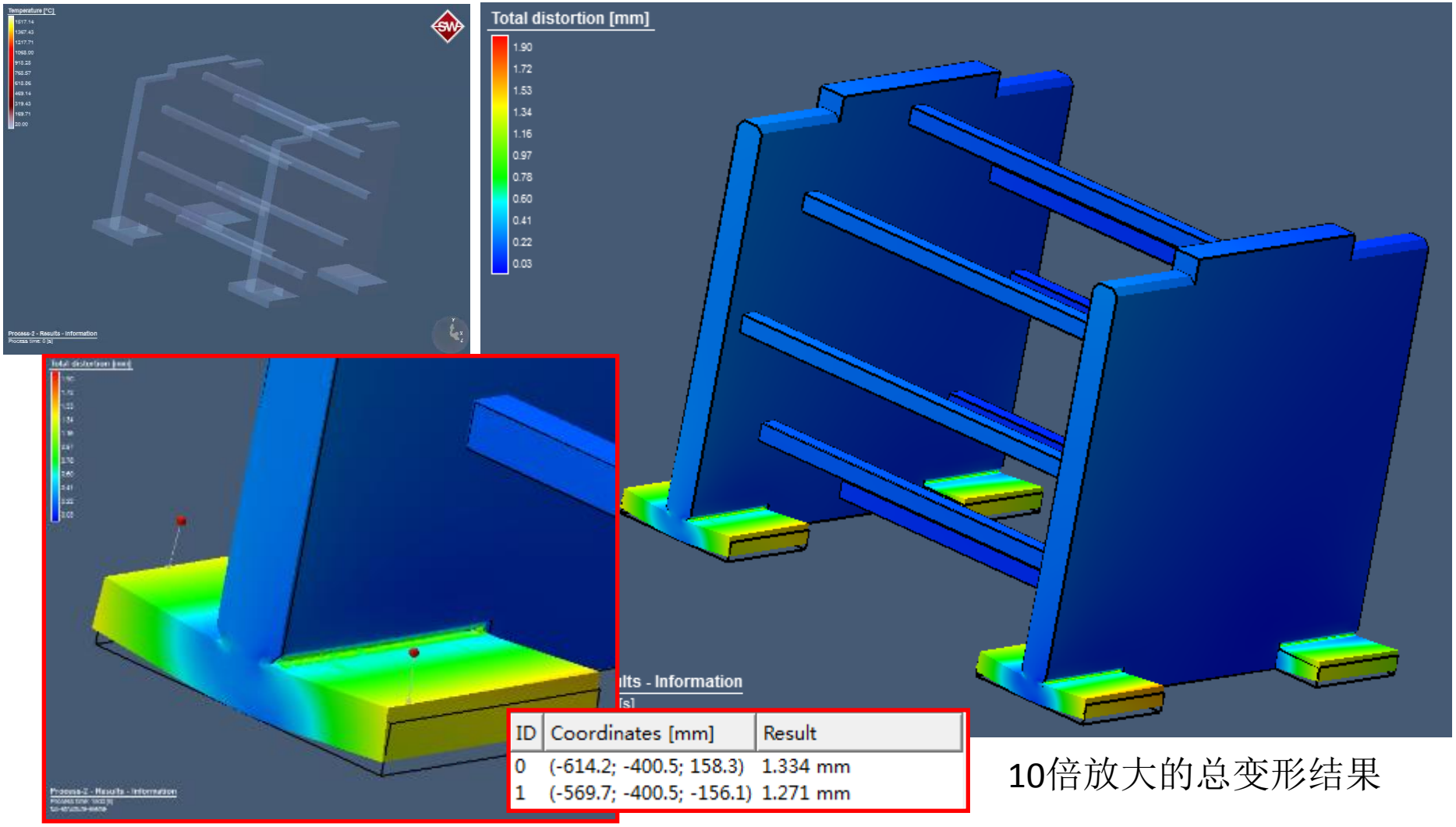


◆ 大厚板多层多道焊接结构仿真

板厚：40,70mm
模型包含8条焊缝，每条焊缝为3层3道

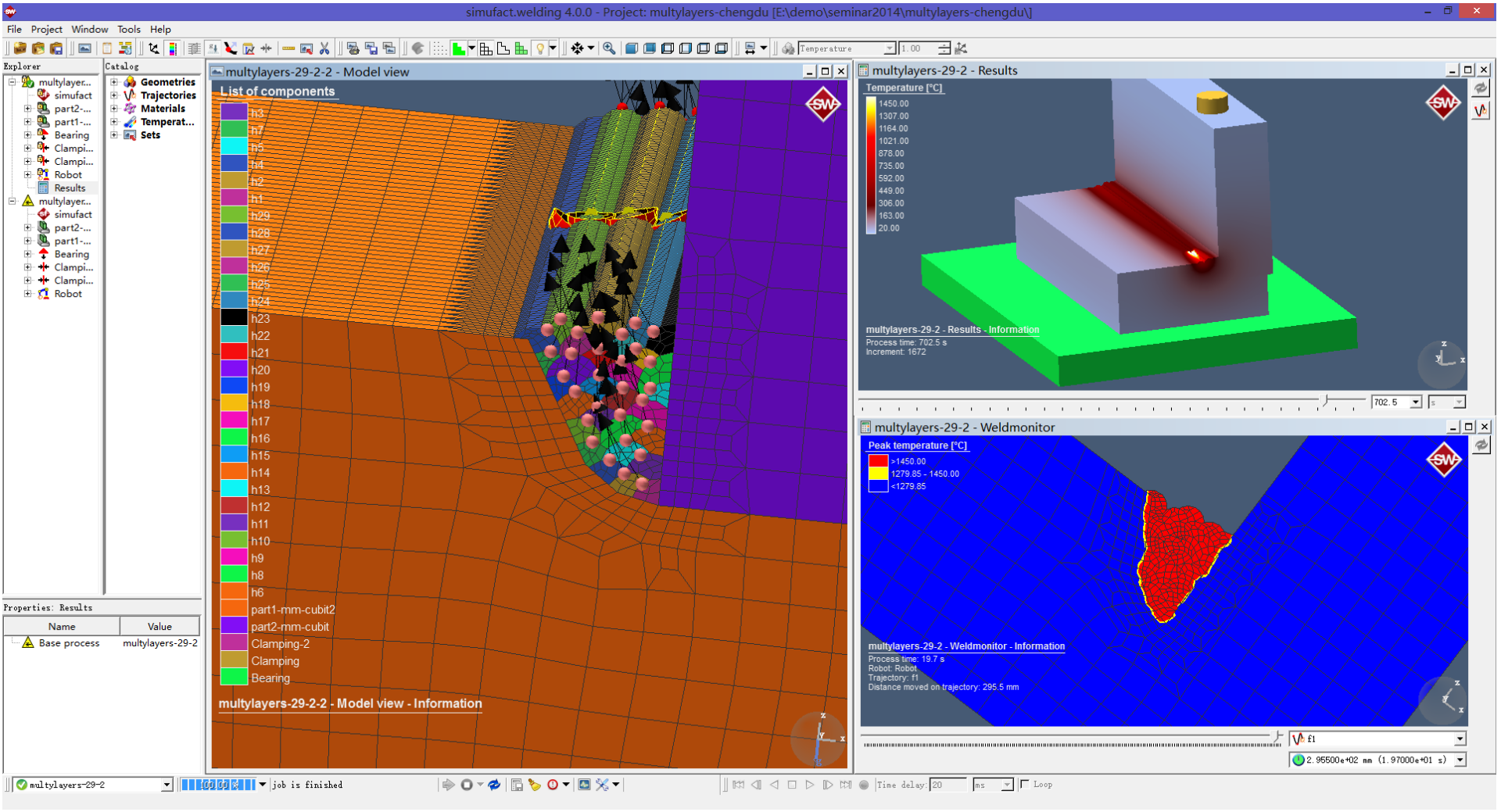


◆ 大厚板多层多道焊接结构仿真



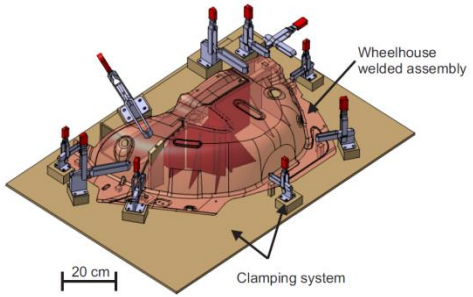
10倍放大的总变形结果

- 大厚板多层多道焊接结构仿真

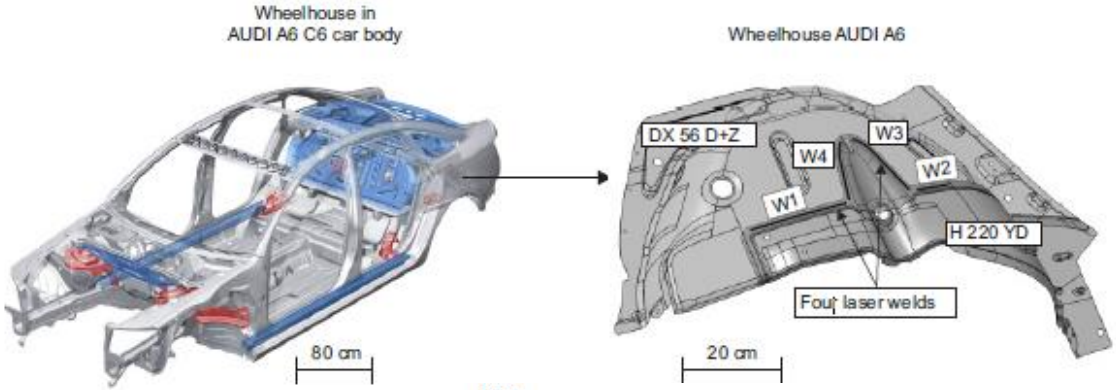


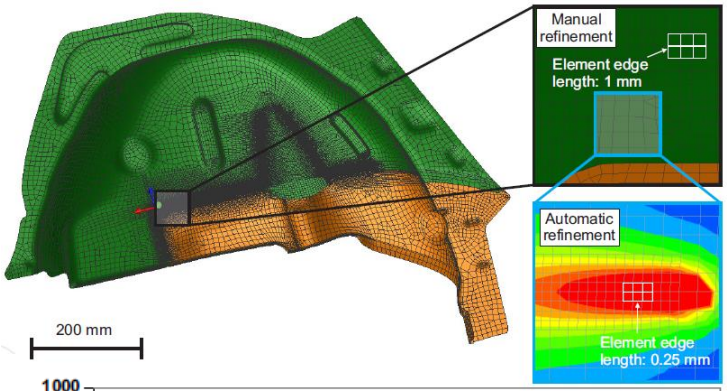
实际案例

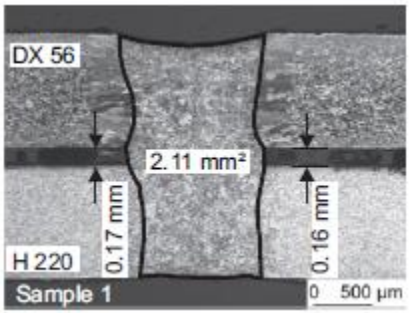
→ A6车身

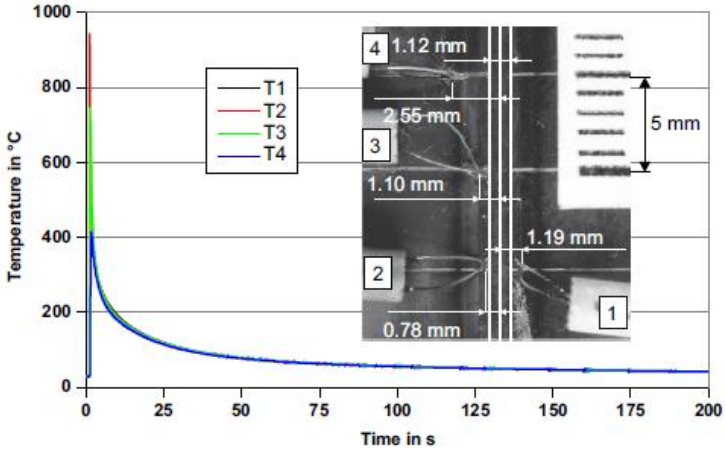


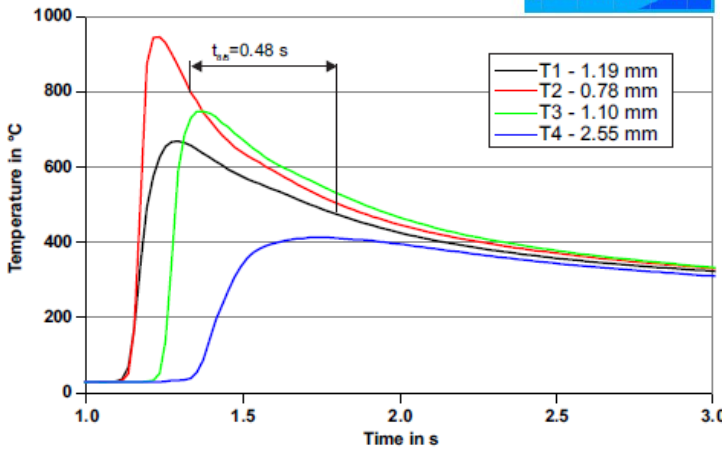
概览







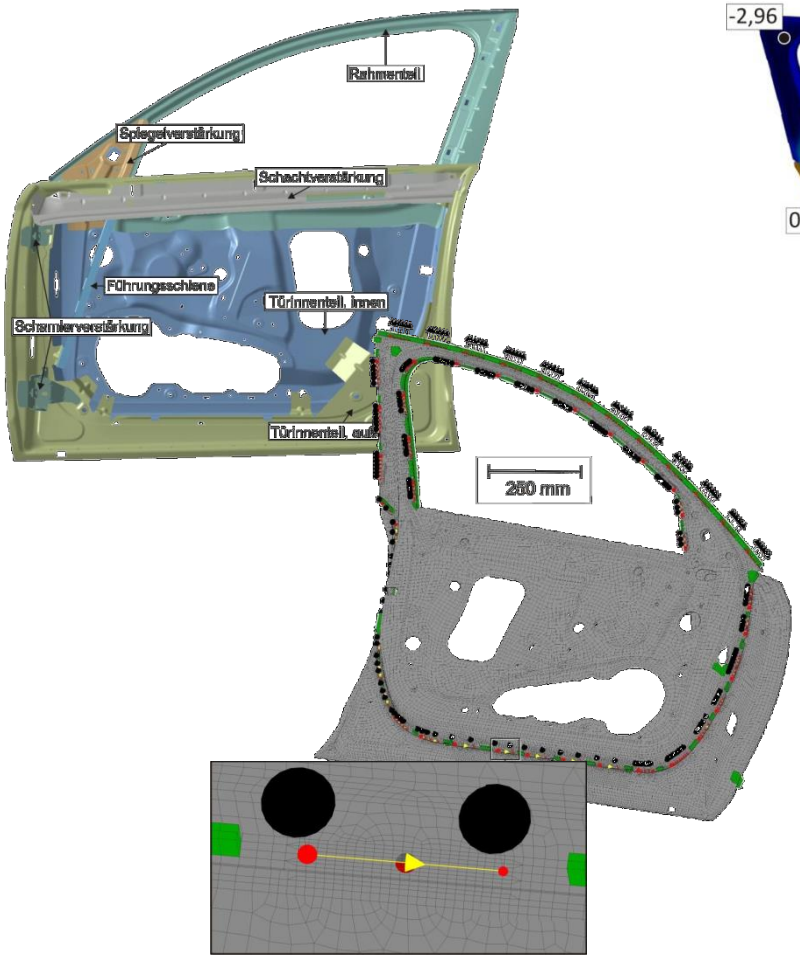


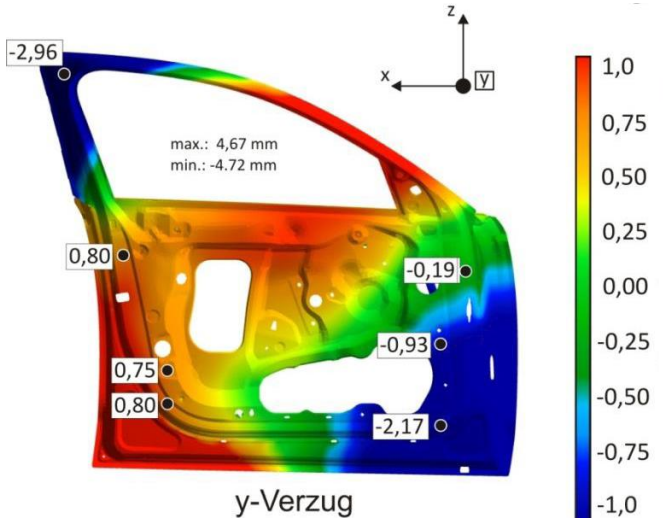


b) Temperature cycles T1-T4 from 1 s to 3 s

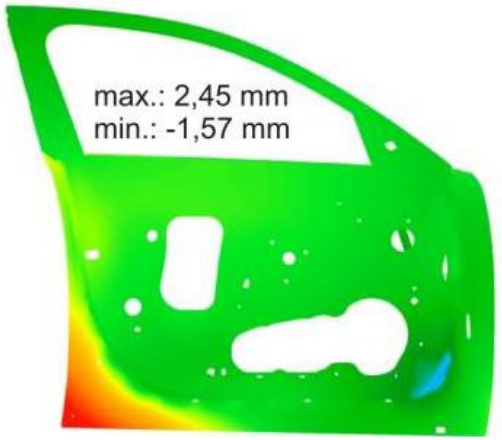
实际案例

→ 铝合金车门激光焊





y-Verzug



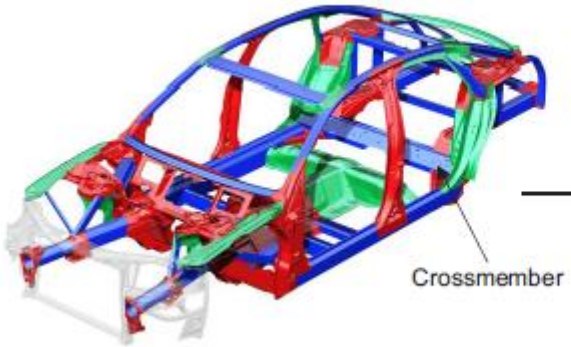
优化后

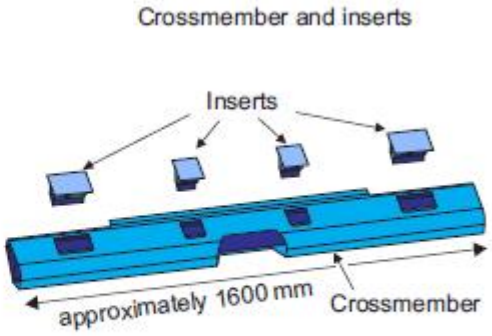
结论:

- 预测焊后变形
- 影响变形的参数研究
- 优化结果
- 减少物理实验次数

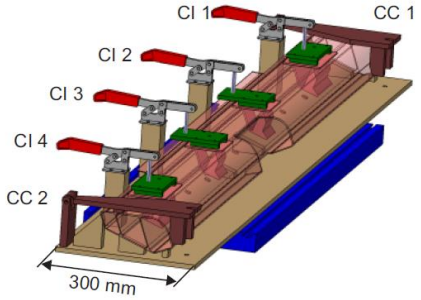
实际案例

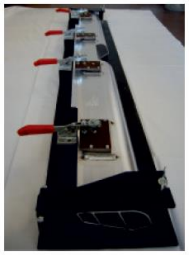
→ **A8 横梁焊接**

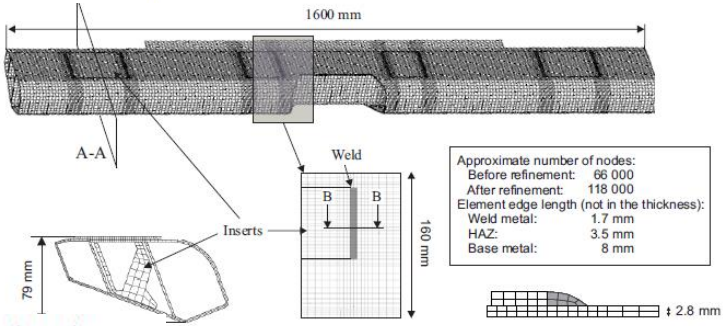




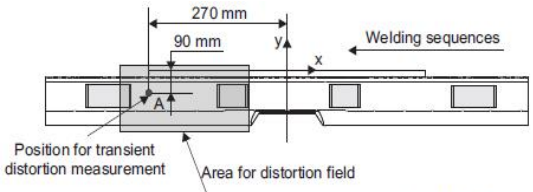
CI: Clamping Insert
CC: Clamping Crossmember

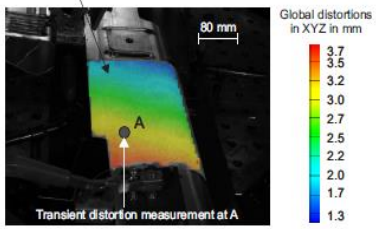




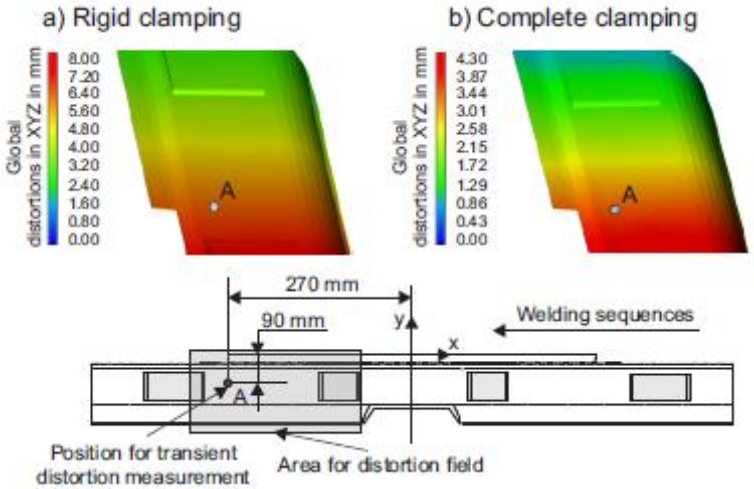


(b) Weld seam area, detailed view (c) Cross section B-B

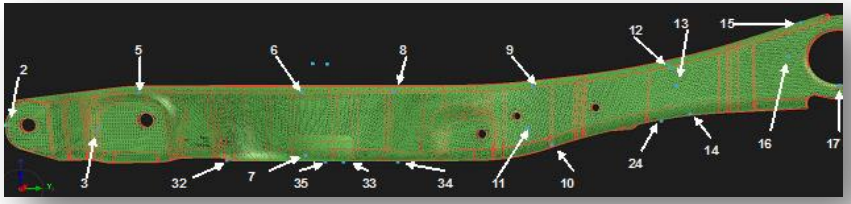


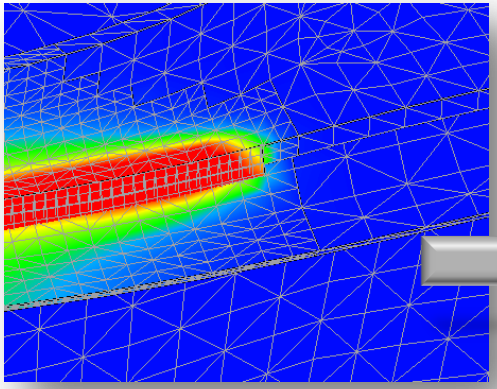


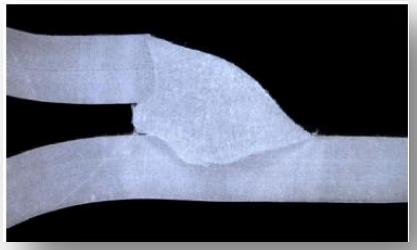
Experimental global distortion field measurement after 800 s, crossbeam, optical 3D deformation analysis system Aramis

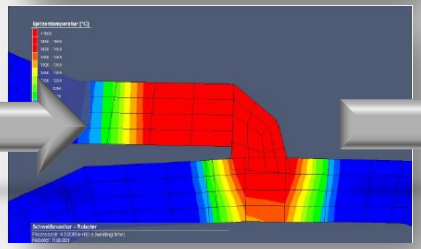


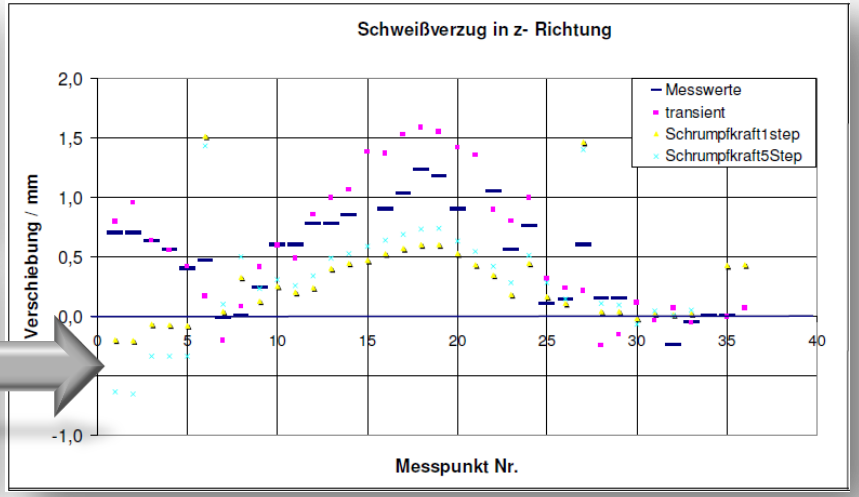
实际案例











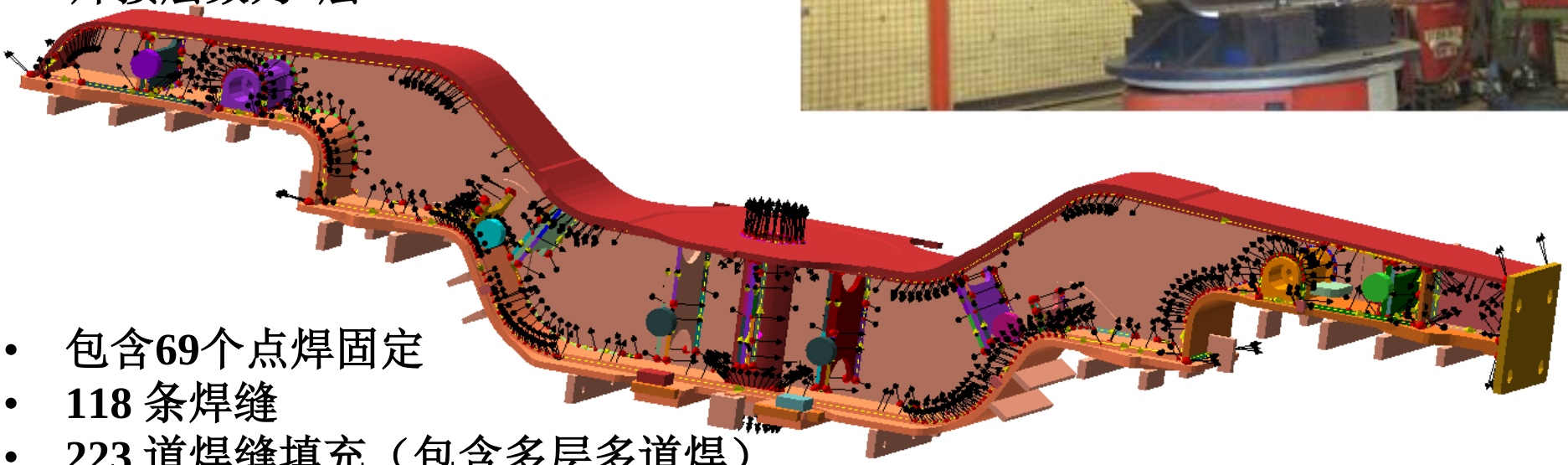
热源区域网格自动细化

热源调整

仿真→ 实验对比

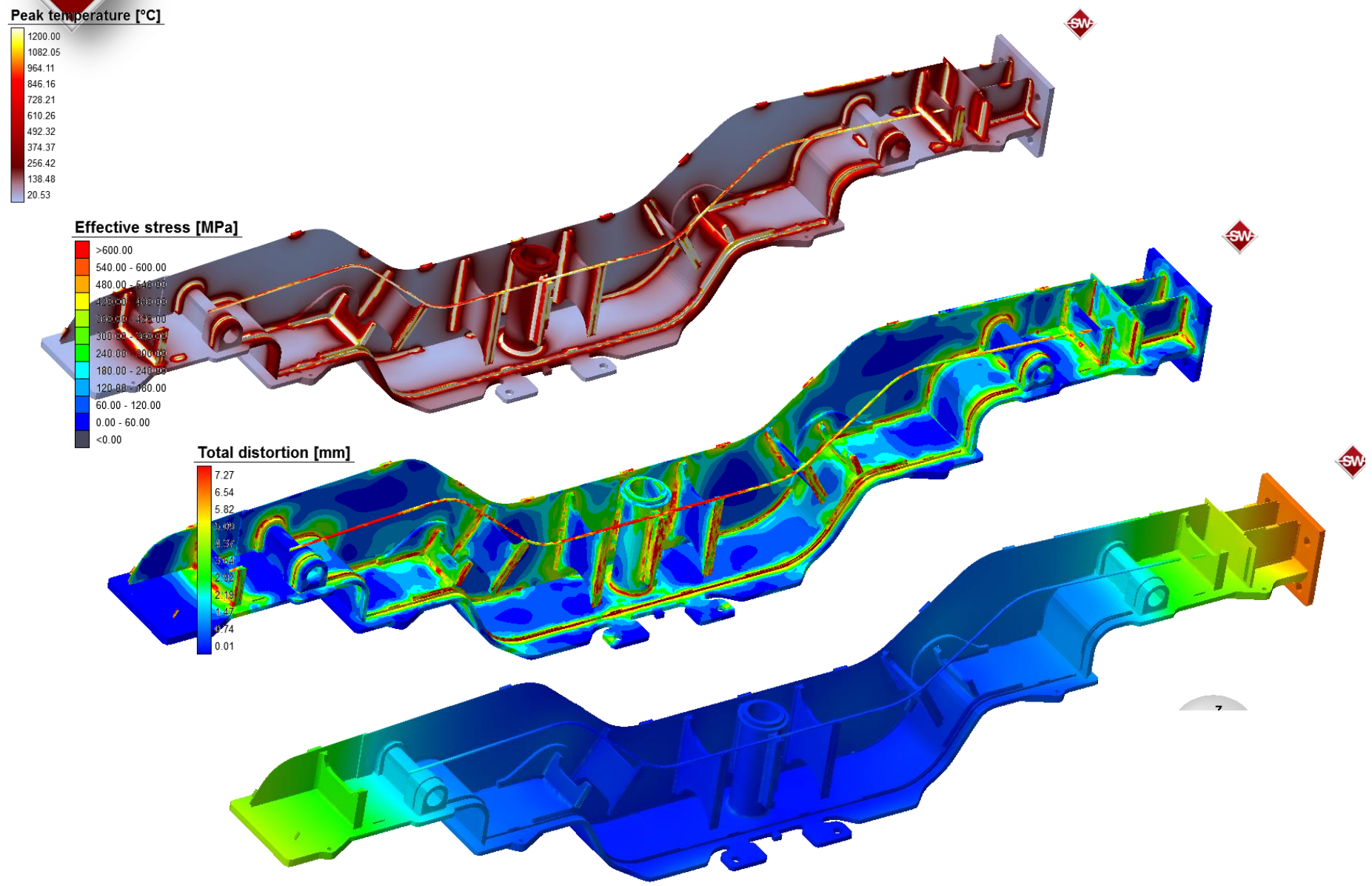
实际案例

- 工件总长2.8 m
- 模型总单元数150 000
- 模型有24个组件焊接而成，焊缝最大焊接层数为4层



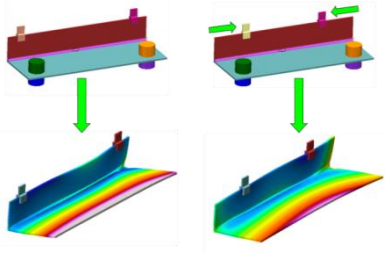
- 包含69个点焊固定
- 118 条焊缝
- 223 道焊缝填充（包含多层多道焊）
- 焊缝总长为56 m
- 焊接持续时间为9138 s
- → 大约20,000个计算时间步
- 计算进程总时间大约为30 000 s

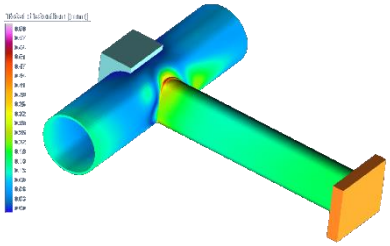
实际案例



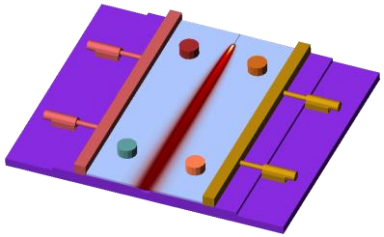
总结

- 焊接模拟可以做到用户友善。simufact.welding提供：
  - 自动网格细分
  - 可处理不兼容网格
  - 焊缝网格生成
  - 快速定义焊接路径及工艺顺序
  - 热源模型及工艺接口
  - 模拟夹具



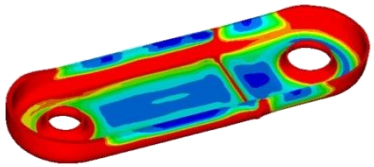


- 快速虚拟优化夹具夹持分布



- 结合simufact.welding和simufact.premap可预测焊接中和焊接后焊件的各相分布

- 结合simufact.welding和simufact.forming可进行工艺链的模拟



- 丰富的材料库及灵活的材料参数定义

Thanks for your attention!

需要做详细了解，请联系：
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电话：13359282259
邮箱：Liwang@ximingsoft.com