

Altair HyperWorks 2024 新版本发布会

AI 赋能技术创新，开启仿真新篇章

2024年8月28日 | 北京



AI 与仿真的融合创新技术与工程实践

马越峰/Technical Director-Simulation/20240828

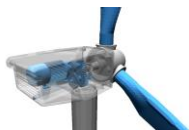
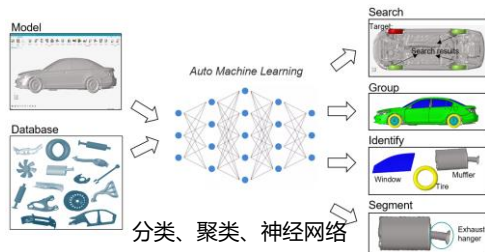
工程复杂度、实时性与仿真技术的变革



机器学习

3

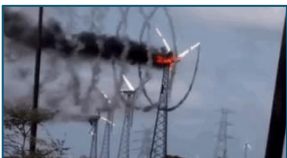
physicsAI, romAI, Rapidminer



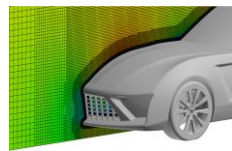
无网格法

2

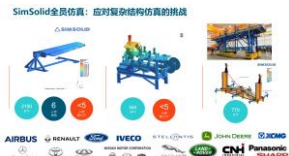
SPH粒子法, LBM格子法, GFEM几何有限元



SPH粒子法



LBM格子法



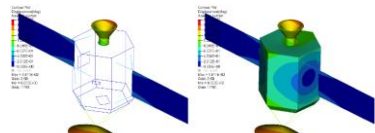
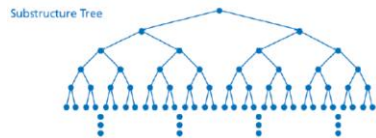
硬件、算法

1

SMP, DMP, GPU

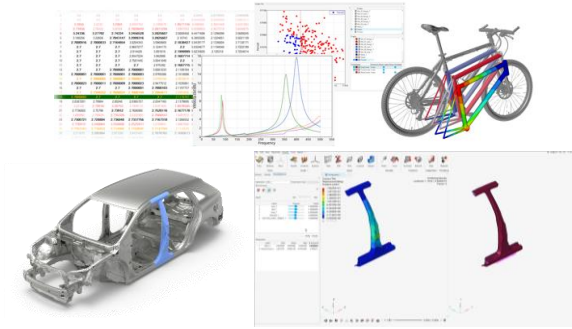


HPC

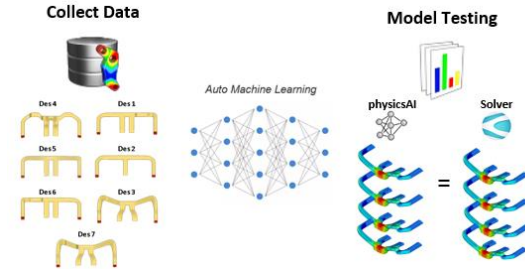


HyperWorks集成的AI技术概览

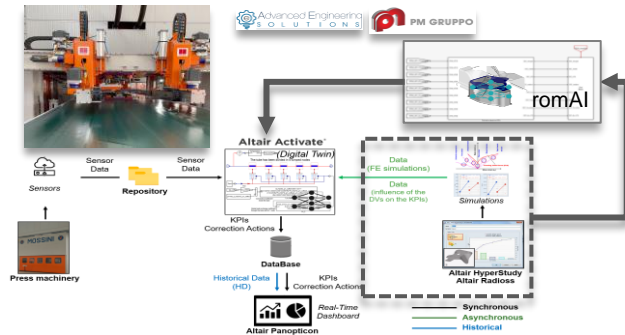
1.Design Explorer基于DOE结果的标量、曲线、云图预测



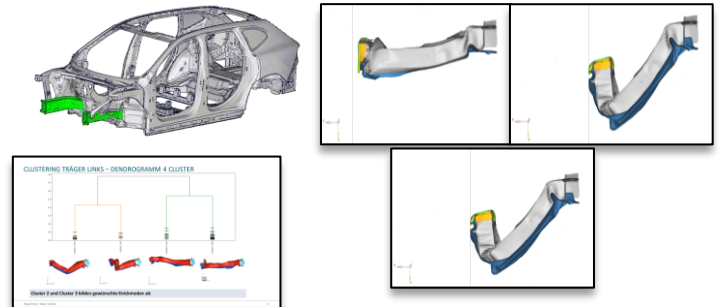
2.physicsAI基于历史仿真数据的无参数云图预测



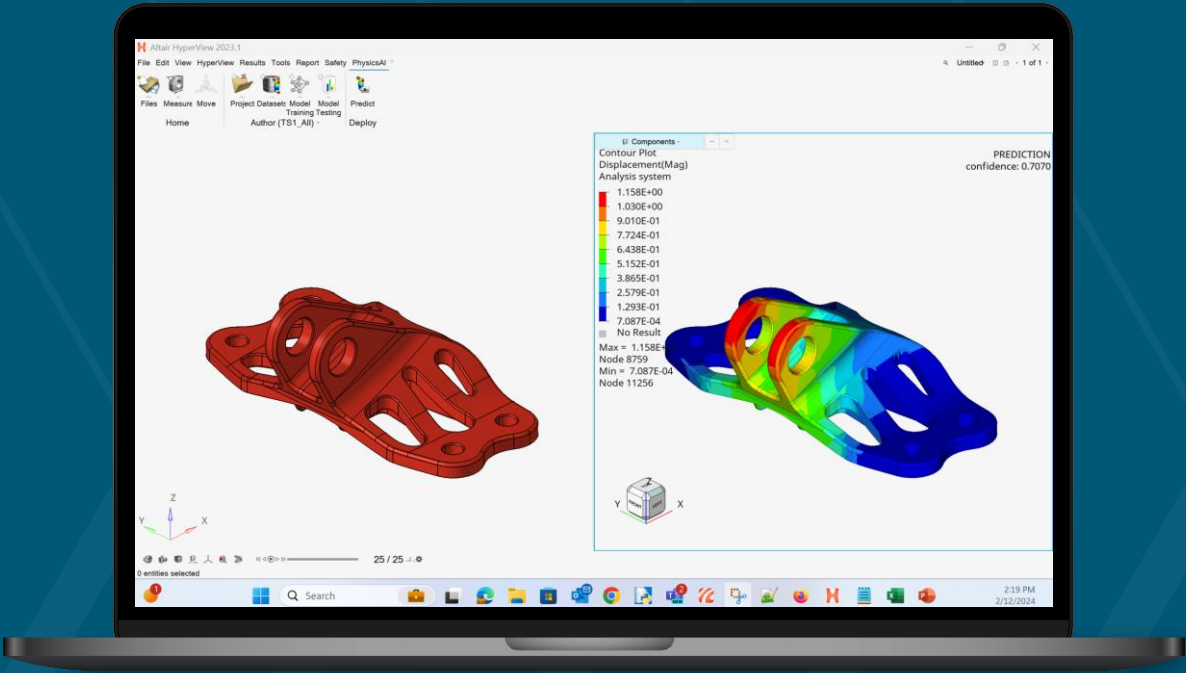
3.romAI 基于AI的模型降阶



4.ExpertAI基于机器学习的模式聚类与优化

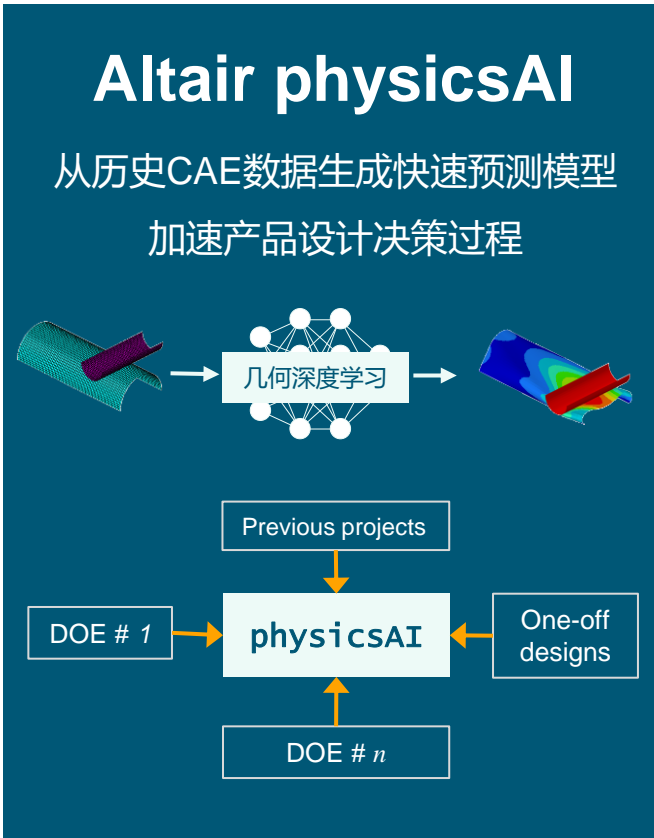
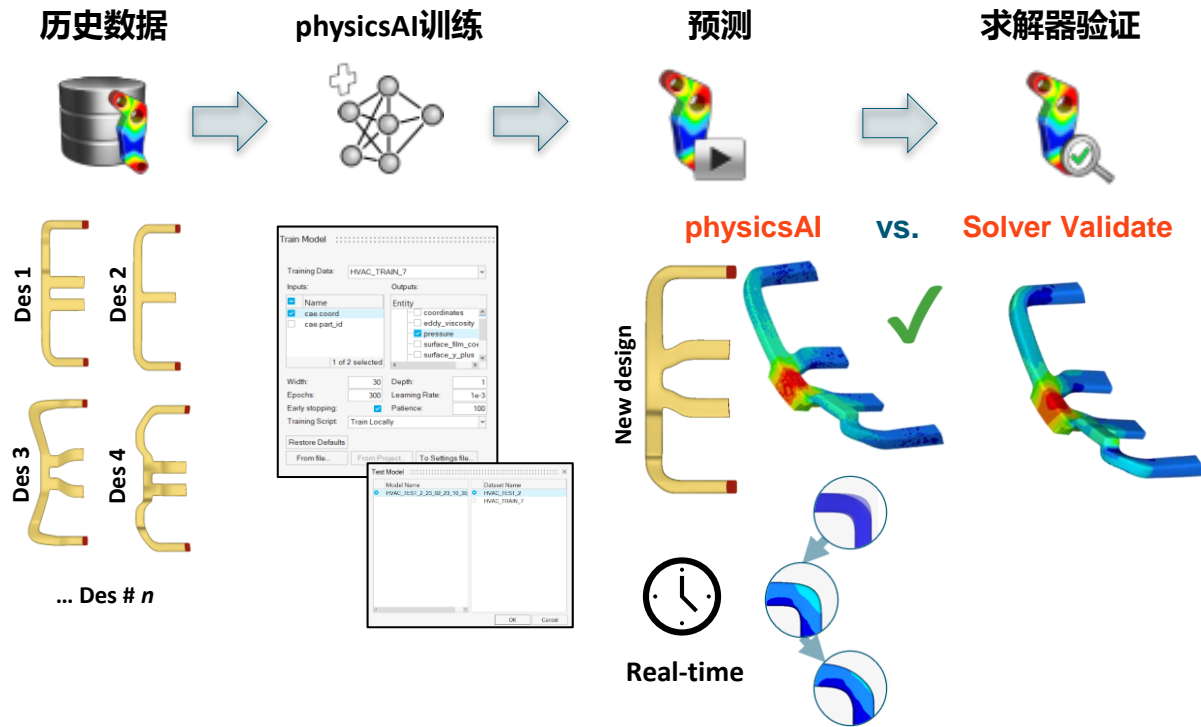


physicsAI: 基于几何深度学习的实时云图预测



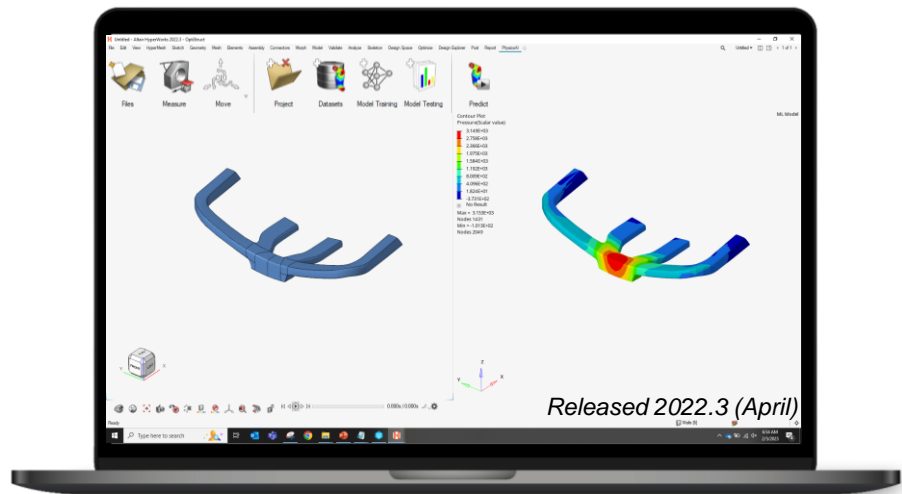
physicsAI – 基于对历史CAE数据的机器学习，加速产品设计

无参学习，本地化模型训练，GPU加速训练



Altair physicsAI 主要功能

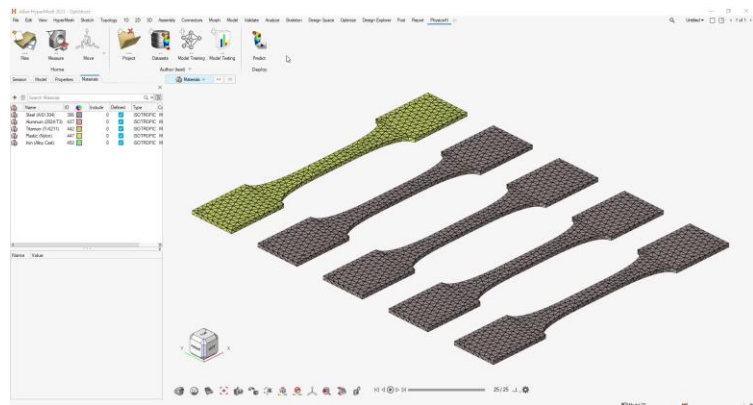
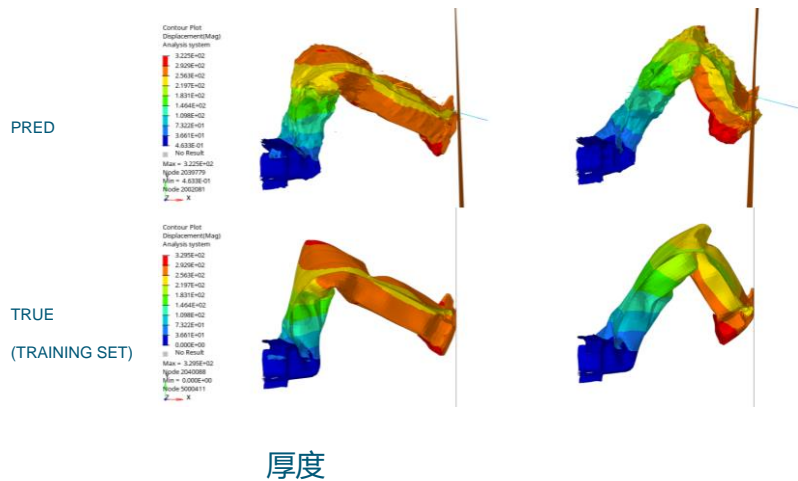
- 无需进行模型参数化
- 桌面级，本地化模型训练，支持GPU加速训练
- physicsAI 使用几何深度学习（GDL, Geometry Deep Learning）技术
- 通过对历史仿真数据的学习，快速实现实时云图预测
- 在网格或几何上预测云图
- 仿真数据可以包含0D、1D、2D、3D网格



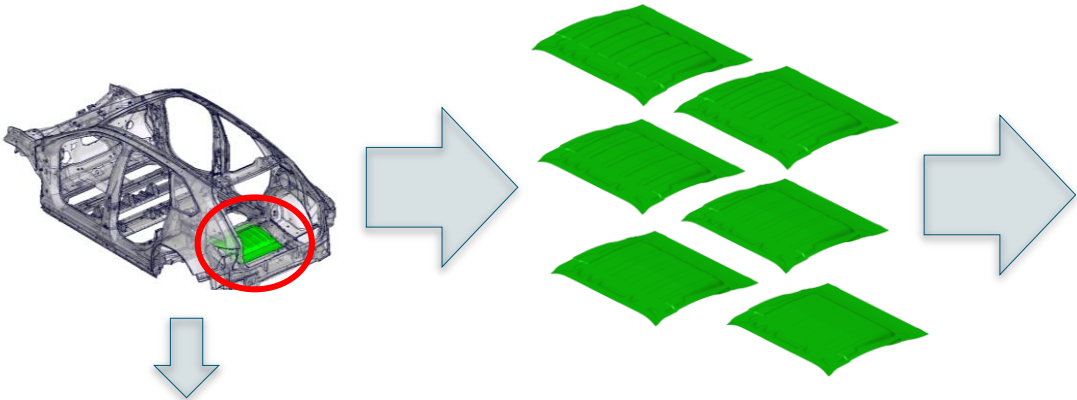
2024新功能

physicsAI 模型参数支持

- 支持解析**材料**和**厚度**信息，并将它们呈现为输入变量
- 需要与每个同名的 **h3d** 文件相对应的 **fem 或 rad 文件**作为输入



physicsAI应用案例: 低速冲击应力



| Dataset | Status | ID | File Name |
|------------|-----------|----|--------------------------------|
| VO03_train | Extracted | 1 | NAS_E_MT_CRO09_1-01-40_PFD.h3d |
| VO03_test | Extracted | 2 | NAS_E_MT_CRO09_1-01-43_PFD.h3d |
| | | 3 | NAS_E_MT_CRO09_1-01-37_PFD.h3d |
| | | 4 | NAS_E_MT_CRO09_1-01-21_PFD.h3d |
| | | 5 | NAS_E_MT_CRO09_1-01-38_PFD.h3d |
| | | 6 | NAS_E_MT_CRO09_1-01-41_PFD.h3d |
| | | 7 | NAS_E_MT_CRO09_1-01-30_PFD.h3d |
| | | 8 | NAS_E_MT_CRO09_1-01-15_PFD.h3d |
| | | 9 | NAS_E_MT_CRO09_1-01-50_PFD.h3d |
| | | 10 | NAS_E_MT_CRO09_1-01-20_PFD.h3d |
| | | 11 | NAS_E_MT_CRO09_1-01-46_PFD.h3d |
| | | 12 | NAS_E_MT_CRO09_1-01-19_PFD.h3d |
| | | 13 | NAS_E_MT_CRO09_1-01-31_PFD.h3d |
| | | 14 | NAS_E_MT_CRO09_1-01-16_PFD.h3d |
| | | 15 | NAS_E_MT_CRO09_1-01-12_PFD.h3d |
| | | 16 | NAS_E_MT_CRO09_1-01-45_PFD.h3d |
| | | 17 | NAS_E_MT_CRO09_1-01-18_PFD.h3d |
| | | 18 | NAS_E_MT_CRO09_1-01-35_PFD.h3d |

Dataset
 Sample size: 46
 Train: 36
 Test: 10

Train physicsAI



Model Testing



Train Model

Training Data: VO03_train

Inputs: Name, cpe_coord, cpe_part_id

Outputs: coordinates, max_damage (f), pl_strain (Shell), pl_strain wo star, Displacement

Width: 30 Depth: 1

Epochs: 300 Learning Rate: 1e-3

Early stopping: Patience: 100

Training Script: Train Locally

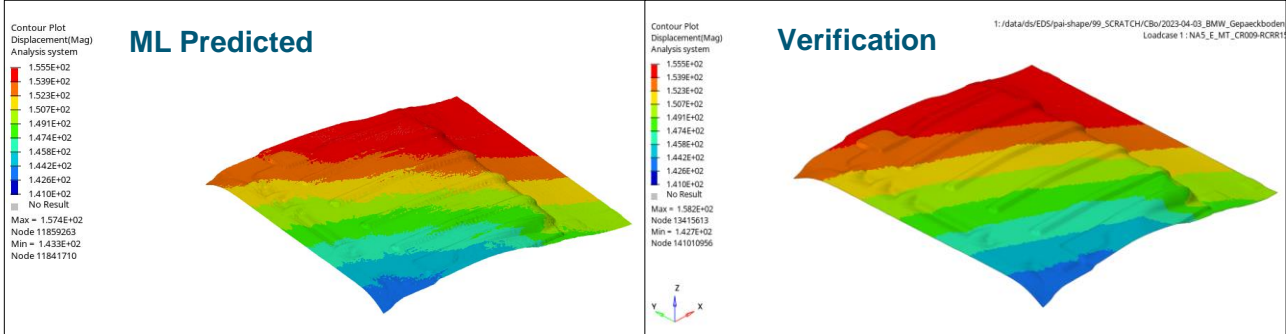
Buttons: Train, Cancel

Model Testing

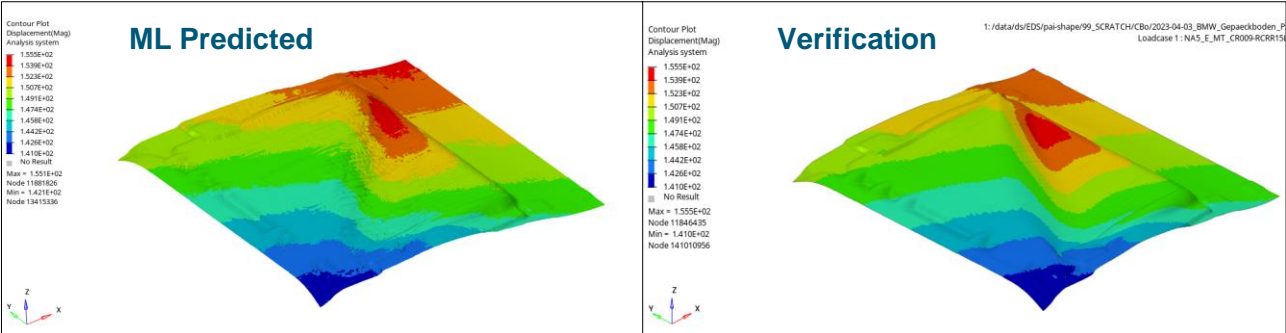
| Wave | 1000 | MultiWave_VO03_train_23_24_14_11_45_55 | VO03_test | 0-75 | Run ID | Max |
|------|------|--|-----------|------|--------|----------|
| | | | | | 1 | 0.891633 |
| | | | | | 2 | 0.131047 |
| | | | | | 3 | 1.131047 |
| | | | | | 4 | 2.262094 |
| | | | | | 5 | 0.511487 |
| | | | | | 6 | 1.022974 |
| | | | | | 7 | 1.488961 |
| | | | | | 8 | 0.891633 |
| | | | | | 9 | 0.871131 |
| | | | | | 10 | 0.477793 |

physicsAI应用案例: 低速冲击应力-仿真和AI

Variant 1



Variant 2



physicsAI应用案例: 加速支架设计流程

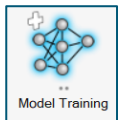
Historical data



Datasets



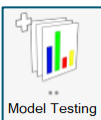
Train physicsAI



Model Training



Validate with Test Data



Model Testing



Real-time exploration

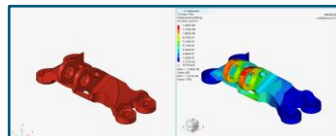
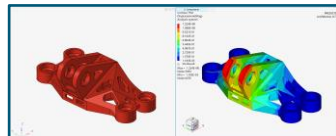
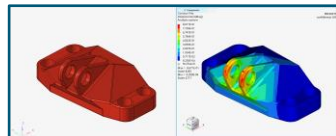
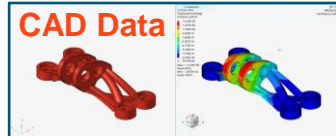
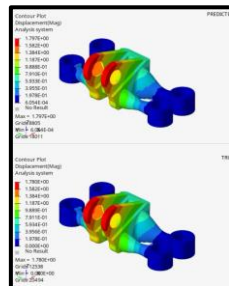
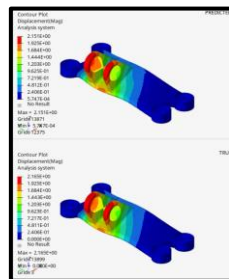
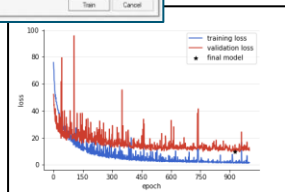
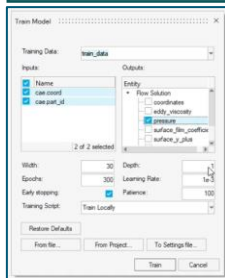
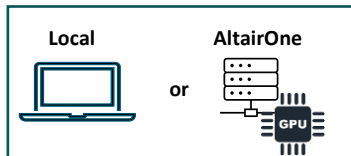
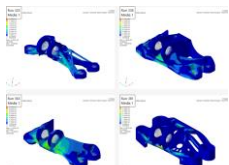


Predict

Training Data

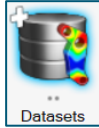


Test Data



physicsAI应用案例:外部空气动力学

Historical data



Datasets



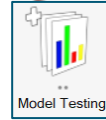
Train physicsAI



Model Training



Validate with Test Data



Model Testing

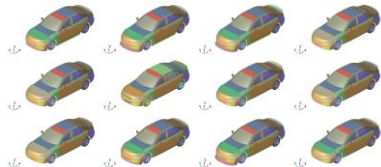


Real-time exploration

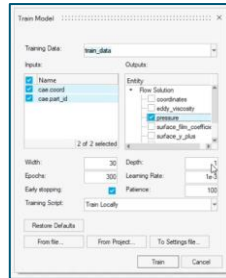
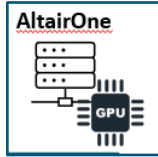
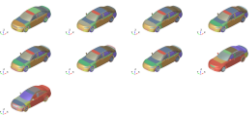


Predict

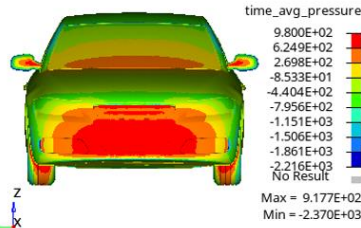
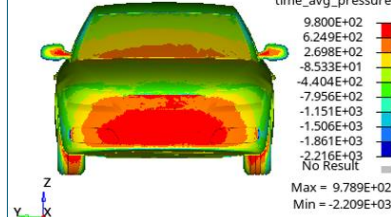
Training Data



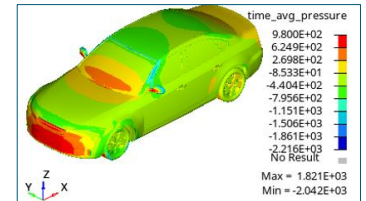
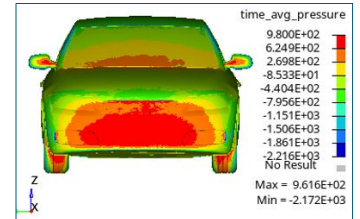
Test Data



ML Runtime 3 min

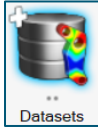


CFD Runtime 750 min



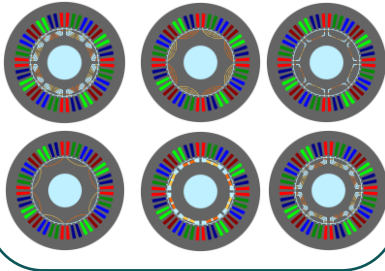
physicsAI应用案例: Motor (Flux 2D)

Historical data

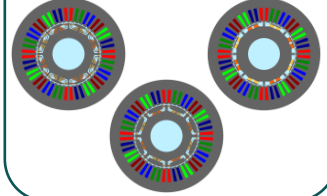


Datasets

Training Data



Test Data



Train physicsAI



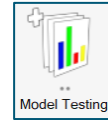
Model Training

Local

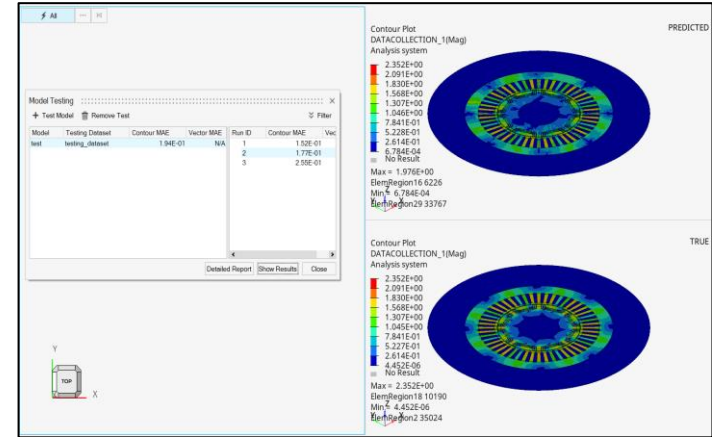


```
View Model Log
Model name: test
[17:21:150] [INFO]: epoch=1482/1500 loss=1.52795e+01
[17:21:151] [INFO]: epoch=1483/1500 loss=5.7105e+01
[17:21:153] [INFO]: epoch=1484/1500 loss=1.52455e+01
[17:21:155] [INFO]: epoch=1485/1500 loss=1.48767e+01
[17:21:156] [INFO]: epoch=1486/1500 loss=1.72022e+01
[17:21:158] [INFO]: epoch=1487/1500 loss=1.50563e+01
[17:21:159] [INFO]: epoch=1488/1500 loss=1.60427e+01
[17:22:01] [INFO]: epoch=1489/1500 loss=1.47243e+01
[17:22:02] [INFO]: epoch=1490/1500 loss=1.41962e+01
[17:22:04] [INFO]: epoch=1491/1500 loss=1.40978e+01
[17:22:06] [INFO]: epoch=1492/1500 loss=1.38360e+01
[17:22:07] [INFO]: epoch=1493/1500 loss=1.31598e+01
[17:22:09] [INFO]: epoch=1494/1500 loss=1.26432e+01
[17:22:10] [INFO]: epoch=1495/1500 loss=1.22425e+01
[17:22:12] [INFO]: epoch=1496/1500 loss=1.20043e+01
[17:22:13] [INFO]: epoch=1497/1500 loss=1.25509e+01
[17:22:15] [INFO]: epoch=1498/1500 loss=1.22455e+01
[17:22:16] [INFO]: epoch=1499/1500 loss=1.19695e+01
[17:22:18] [INFO]: epoch=1500/1500 loss=1.18318e+01
[17:22:18] [INFO]: Restoring model from the best epoch: 1500 (loss: 1.18318e+01)
[17:22:18] [INFO]: -----
[17:22:18] [INFO]: 6: Train summary
[17:22:18] [INFO]: Total train time: 0:14:35.05:764974
[17:22:18] [INFO]: -----
 Refresh every:  sec 
```

Testing



Model Testing



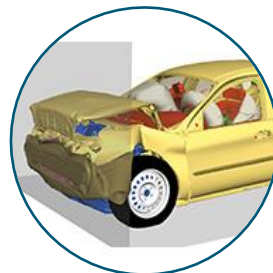
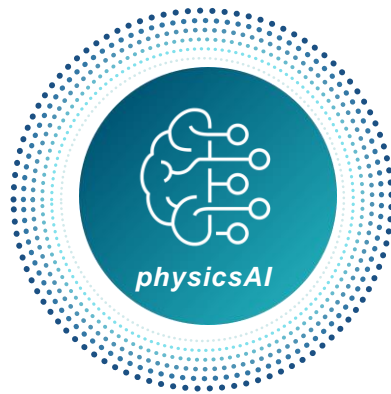
physicsAI特点：学科中立+无需人为设置几何参数



Heavy Machinery



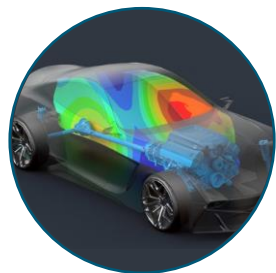
Structural



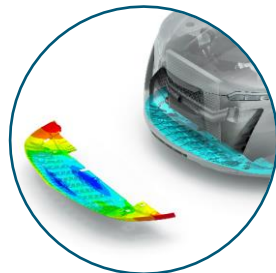
Crash



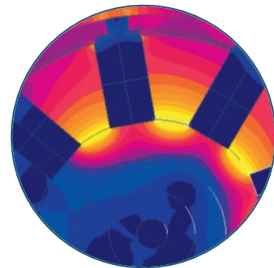
Aerospace



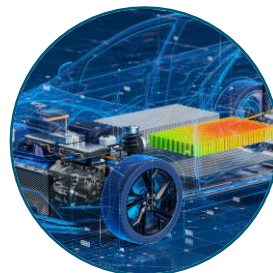
NVH



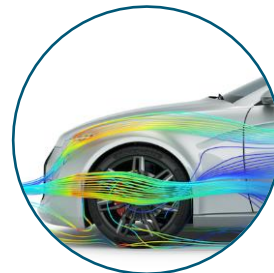
Manufacturing



Electro-
magnetics

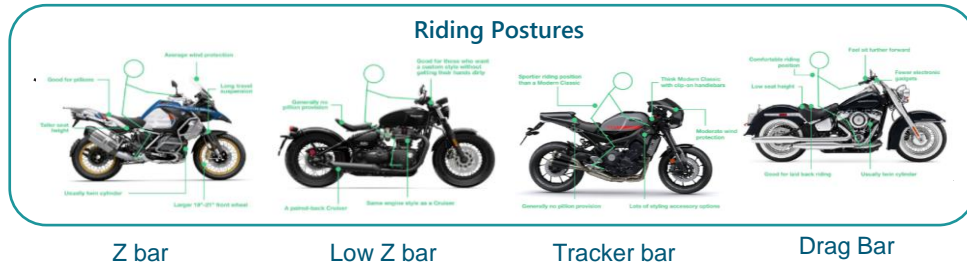


Thermal

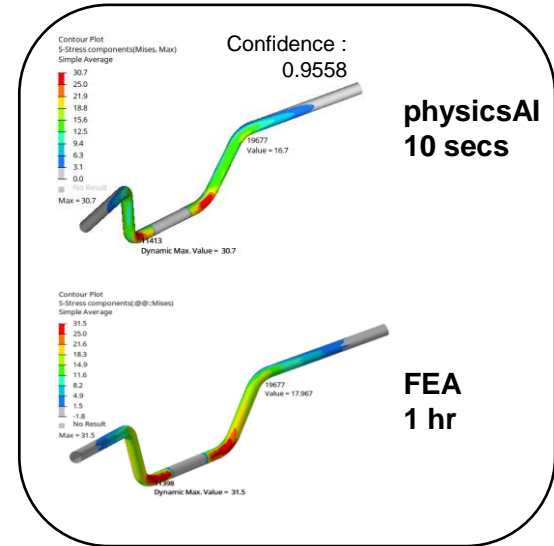


Fluid

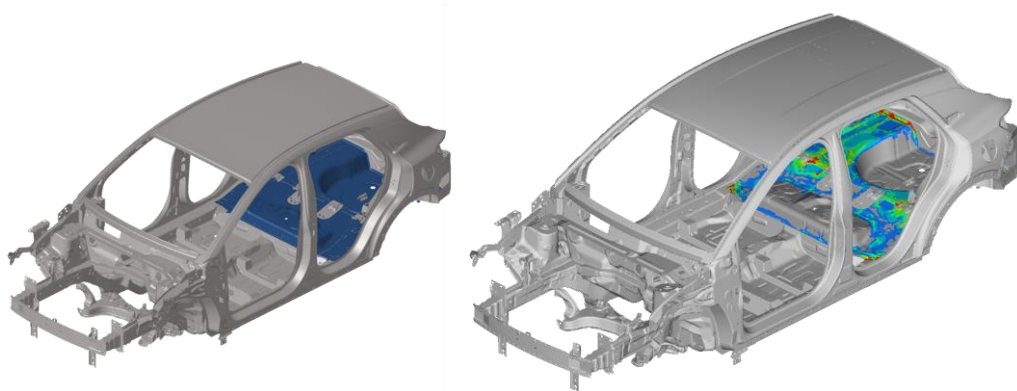
physicsAI应用案例：摩托车手把



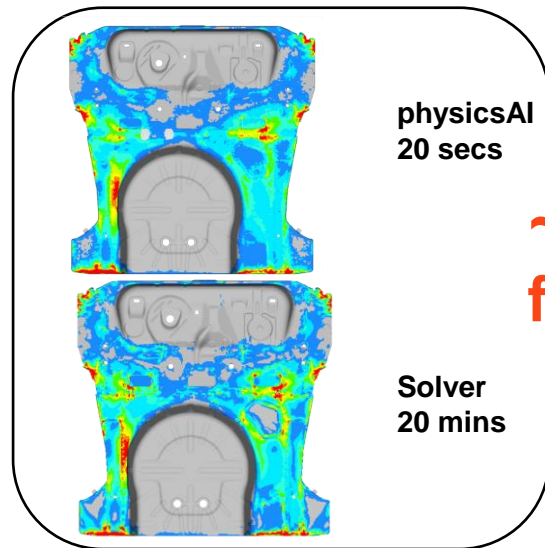
摩托车上的把手是其人体工程学的重要组成部分。
它会影响摩托车在转弯时的特性、骑手骑乘姿态以及舒适性



physicsAI应用案例:后地板FORD Brazil

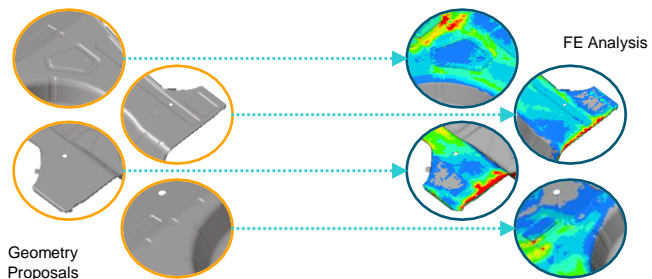


为了满足车身扭转刚度和应力要求，需要进行多次迭代

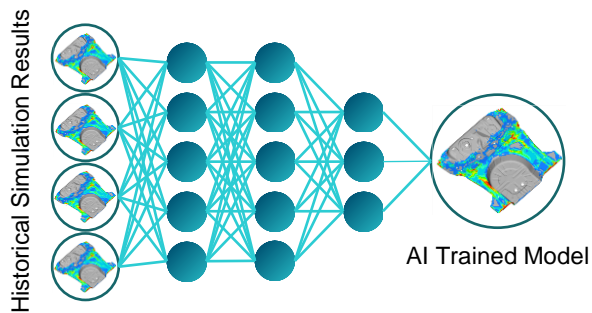


~50X
faster

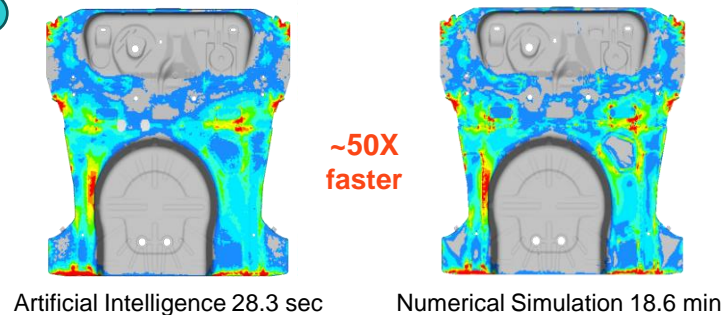
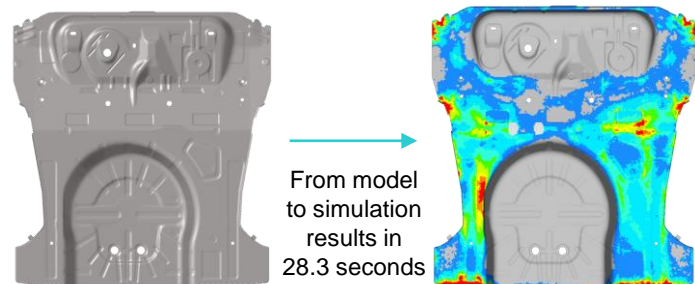
physicsAI应用案例:后地板FORD Brazil



STEP1: 历史仿真数据



STEP2: 训练模型



STEP3: 预测新模型的结果

physicsAI应用案例：成都捷普

客户背景与现状

比亚迪子公司，主要生产iPhone、iPad零部件、机壳、屏幕等产品。有大量零部件工艺仿真需求，如模压，注塑，切削等。

用户从简单模型开始到实际仿真工况，使用physicsAI尝试了不同场景，反馈非常积极，正在推进采购。

应用场景示例

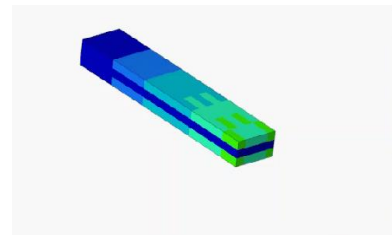
- **悬臂梁瞬态仿真**，验证physicsAI适用于瞬态仿真云图的预测
- **金属模压成型仿真**，预测不同胚料形状在模压工艺后的成型状态，仅用8组Abaqus历史仿真结果进行训练，反馈预测精度非常好
- **刀头切削仿真**，预测不同设计下刀刃应力分布。由于仿真软件很小众，我们与捷普工程师一起探索将仿真结果转换为h3d的技术路线，然后使用physicsAI进行预测

成功经验

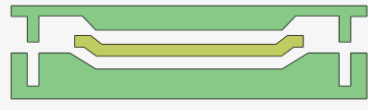
physicsAI非常适合应用于工艺仿真云图预测，此类仿真特点：零件数量少、工艺仿真软件杂，仿真时间长，设置繁琐，软件一般比较封闭。

客户愿意学习尝试新事物也很重要，在此过程中，捷普工程师非常愿意花时间钻研。

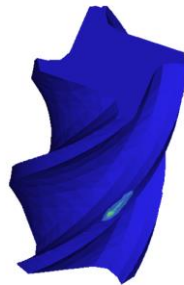
客户反馈问题及时跟进支持，与用户保持沟通。



悬臂梁瞬态云图预测

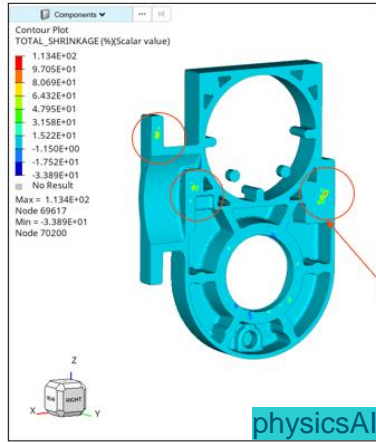


金属模压成型云图预测



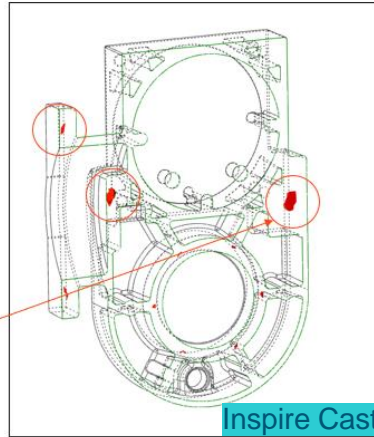
刀头切削云图预测

physicsAI应用案例：铸造工艺

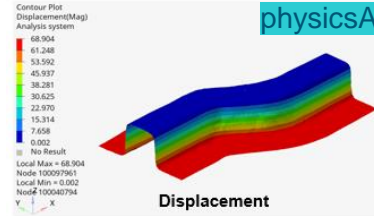


physicsAI

physicsAI预测铸缩孔位置

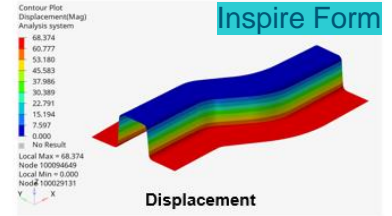


Inspire Cast



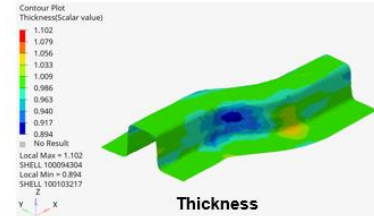
physicsAI

Displacement

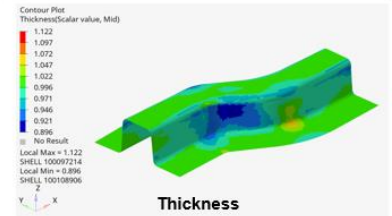


Inspire Form

Displacement

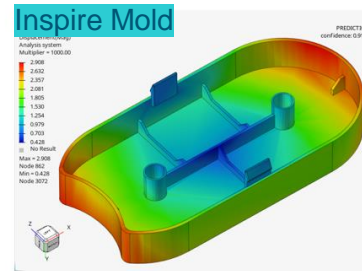
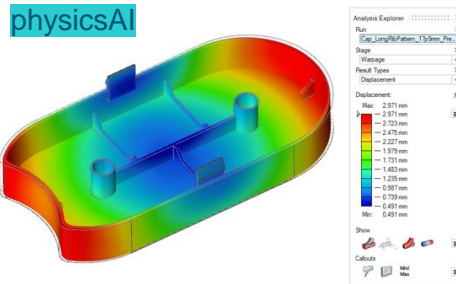


Thickness



Thickness

physicsAI预测冲压减薄率



physicsAI预测模流翘曲变形

romAI: 基于AI的模型降阶与系统仿真

数据准备

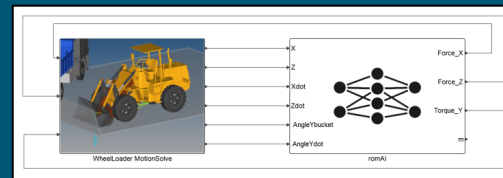
| | A | B | C | D | E | F | G | H | I |
|----|-------|---------|---------|----------|----------|----------|----------|----------|----------|
| 1 | time | Xref_mm | Yref_mm | X_mm | Y_mm | X_dot | Y_dot | TX_deg | TY_deg |
| 2 | 0 | 0 | 0 | 0.14798 | 2.29719 | 0.002035 | -5.00691 | -0.13134 | -0.75129 |
| 3 | 0.005 | 0 | 0 | 0.14781 | 2.272156 | 0.001635 | -4.02188 | -0.1229 | -0.64688 |
| 4 | 0.01 | 0 | 0 | 0.147817 | 2.256972 | 0.000992 | -2.43939 | -0.11618 | -0.66437 |
| 5 | 0.015 | 0 | 0 | 0.14782 | 2.247762 | 0.000601 | -1.47957 | -0.11099 | -0.7383 |
| 6 | 0.02 | 0 | 0 | 0.147823 | 2.242176 | 0.000365 | -0.8974 | -0.107 | -0.83284 |
| 7 | 0.025 | 0 | 0 | 0.147824 | 2.238788 | 0.000221 | -0.5443 | -0.10394 | -0.52927 |
| 8 | 0.03 | 0 | 0 | 0.147825 | 2.236733 | 0.000134 | -3.46057 | -0.10162 | -1.01857 |
| 9 | 0.035 | 0 | 0 | 0.147825 | 2.204182 | 6.809494 | -9.0794 | -0.09988 | -0.74168 |
| 10 | 0.04 | 0 | 0 | 0.21502 | 2.145039 | 18.91002 | -2.3765 | -0.08022 | -0.38267 |



降阶ROM

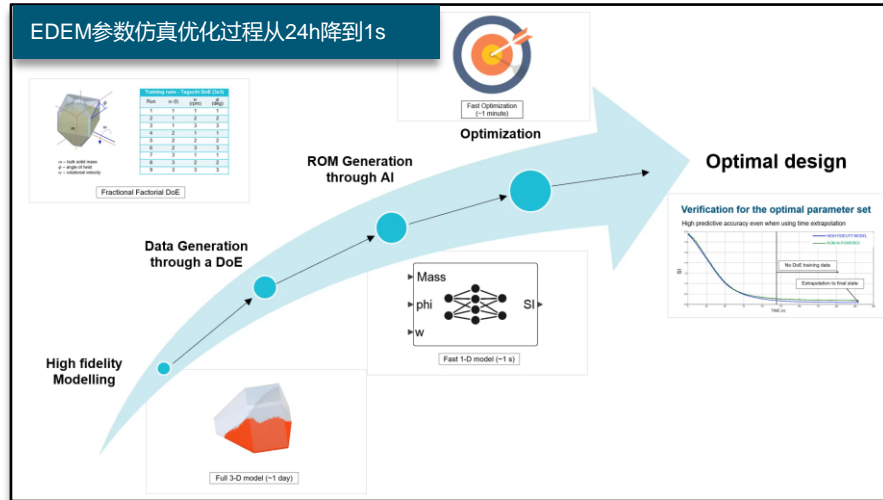
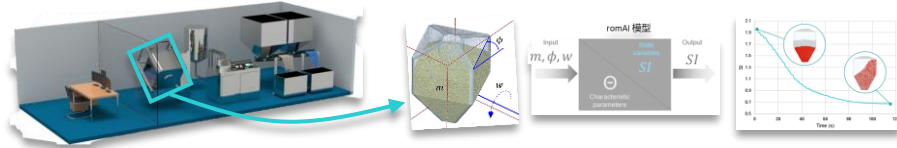


快速系统仿真



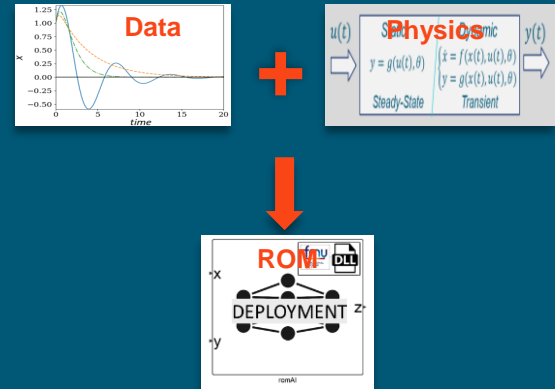
romAI – 复杂仿真的降阶建模，提升系统响应仿真效率

模型降阶加速复杂系统耦合仿真及优化设计



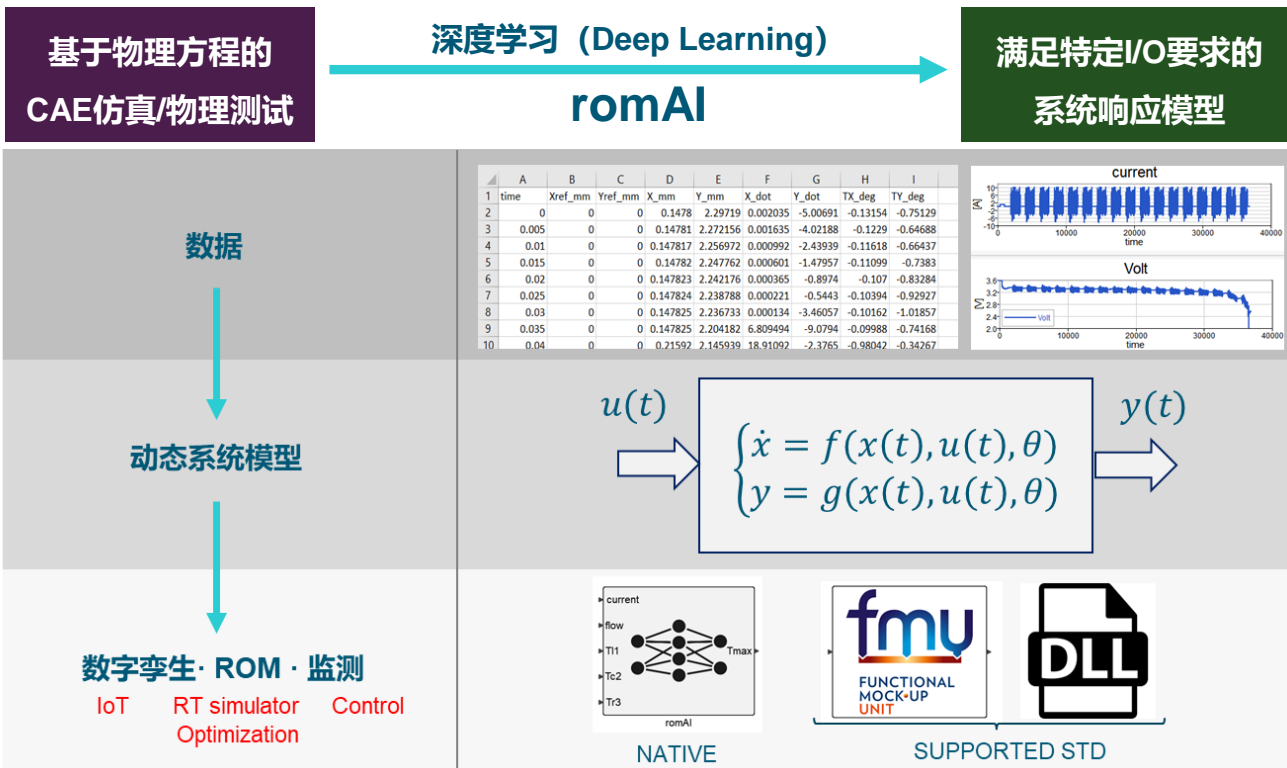
Altair romAI

基于深度学习的降阶建模工具
成就数字孪生系统建模核心



基于AI和经典系统理论的模型降阶，数字孪生关键技术

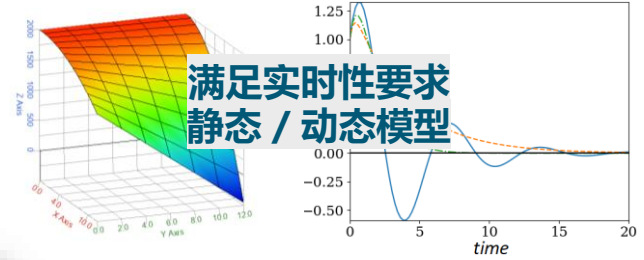
机理研究/物理测试与数据应用的火花碰撞



Altair® romAI™

| | A | B | C | D | E | F | G | H | I |
|----|-------|---------|---------|----------|----------|----------|----------|----------|----------|
| 1 | time | Xref_mm | Yref_mm | X_mm | Y_mm | X_dot | Y_dot | TX_deg | TY_deg |
| 2 | 0 | 0 | 0 | 0.1478 | 2.29719 | 0.002035 | -5.00691 | -0.13154 | -0.75129 |
| 3 | 0.005 | 0 | 0 | 0.14781 | 2.272156 | 0.001635 | -4.02188 | -0.1229 | -0.64688 |
| 4 | 0.01 | 0 | 0 | 0.14782 | 2.247111 | 0.001235 | -3.9939 | -0.11618 | -0.66437 |
| 5 | 0.015 | 0 | 0 | 0.14783 | 2.222066 | 0.000835 | -3.9957 | -0.11099 | -0.7383 |
| 6 | 0.02 | 0 | 0 | 0.14784 | 2.197021 | 0.000435 | -3.9974 | -0.107 | -0.83284 |
| 7 | 0.025 | 0 | 0 | 0.147824 | 2.238788 | 0.000221 | -0.5443 | -0.10394 | -0.92927 |
| 8 | 0.03 | 0 | 0 | 0.147825 | 2.236733 | 0.000134 | -3.46057 | -0.10162 | -1.01857 |
| 9 | 0.035 | 0 | 0 | 0.147825 | 2.204182 | 6.809494 | -9.0794 | -0.09988 | -0.74168 |
| 10 | 0.04 | 0 | 0 | 0.21592 | 2.145939 | 18.91092 | -2.3765 | -0.98042 | -0.34267 |

仿真或测试数据



满足实时性要求
静态 / 动态模型



轮式装载机案例

目标

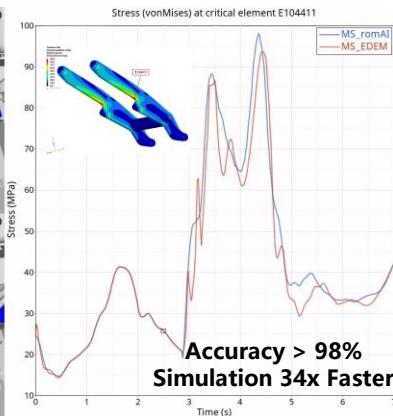
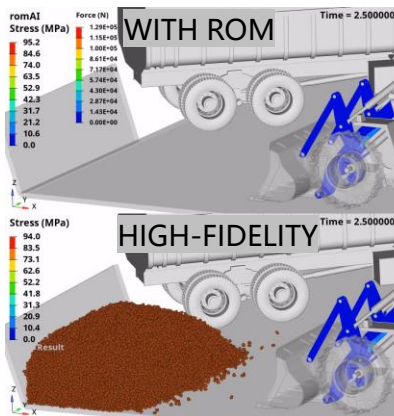
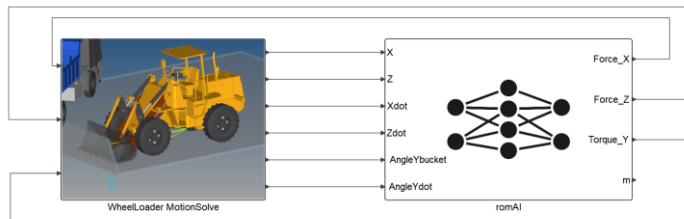
加速复杂系统耦合仿真用于优化分析

方案

创建动态降阶模型用于精确评估铲斗和颗粒物料之间的反作用力

价值

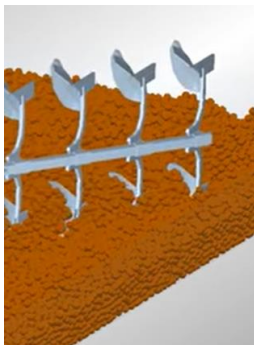
- 提速比 34，运行时间从 680s 减少为 20s!
- 精度 > 98% (与高精度联合仿真相比)



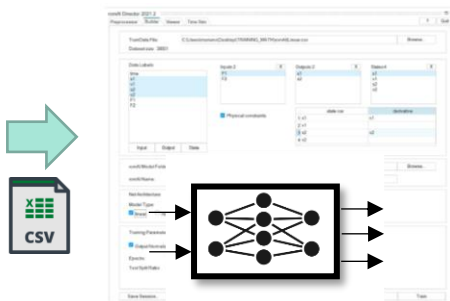
利用降阶模型ROM提升实施仿真器性能和精度



EDEM



romAI/TwinActivate

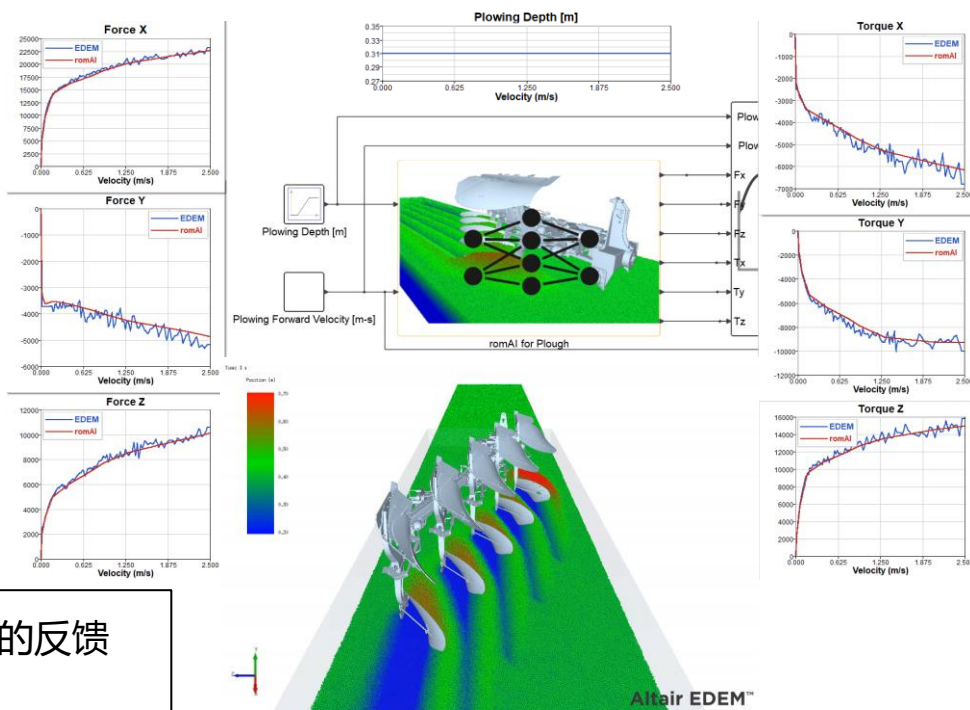


模型部署



实时仿真器硬件

- 犁耕阶段更逼真的反馈
- 更好的消耗估算



加速驾驶舱内HVAC仿真

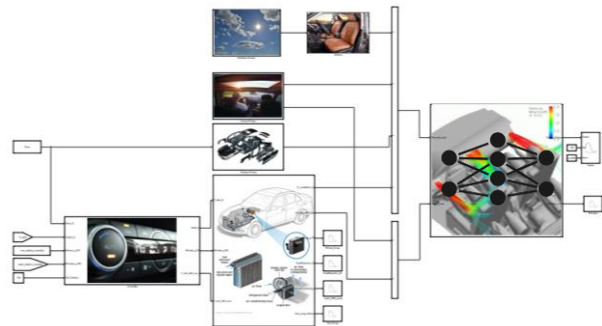
目标

加速热流动力学系统级联合仿真

方案

建立热泵的精确模型用于不同控制策略的虚拟测试仿真

- **GT-suite:** 1D HVAC 路仿真
- **romAI:** 创建舱内温度动态降阶模型替代3D CFD仿真, 然后模型以FMU输出并集成于GT-suite.



价值

- 仿真时间从 **20-30小时** 减少为 **20分钟!**
- 最大误差 1.2 °C (与高精度仿真模型相比)
- romAI 模型精度结果优于采用高斯过程回归方法的模型 (高斯回归模型最大误差为 4.4°C)

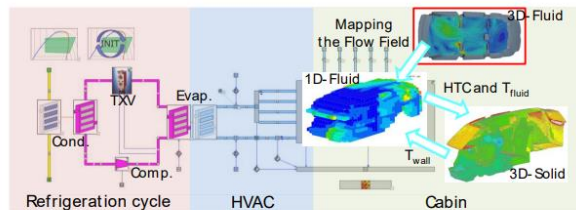


Fig.1 1D-3D coupled Air-Conditioning CFD model

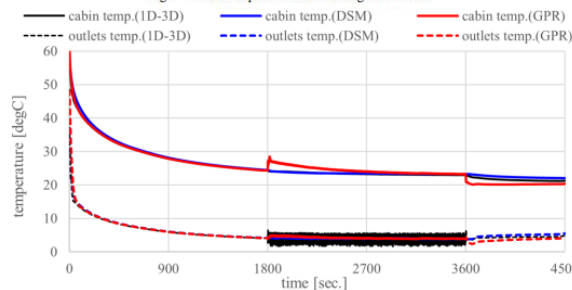


Fig.3 Calculation result for Case 14 (DSM: Dynamic Surrogate Model, GPR: Gaussian Process Regression)

支架关键位置应力预测虚拟传感器

目标

仅通过两点应变值预测支架应力及载荷

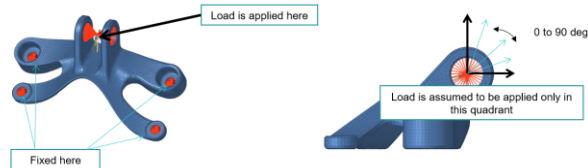
方案

创建支架的精确的降阶模型

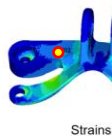
- OptiStruct: 创建FE模型，用于生成基于已知载荷下关键位置的应力应变数据
- romAI: 基于有限元分析数据创建降阶模型
- Activate: 降阶模型部署运行，用于基于应变值预测应力及载荷

价值

- 仅从2点位置应变预测关键位置应力及载荷
- 仅用1组有限元仿真生成ROM
- 平均精度 > 95%



INPUT



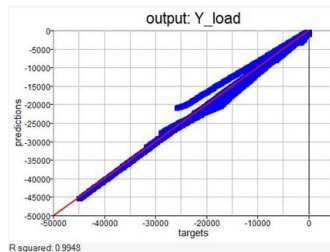
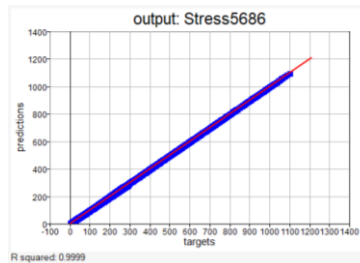
romAI



OUTPUT

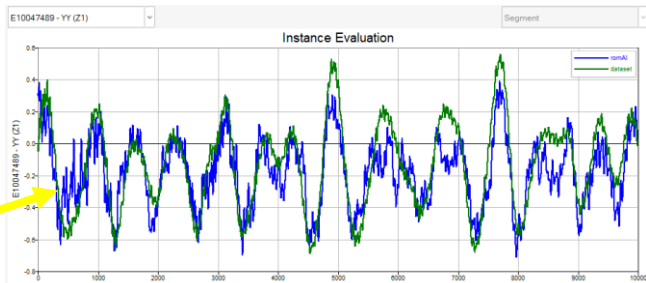
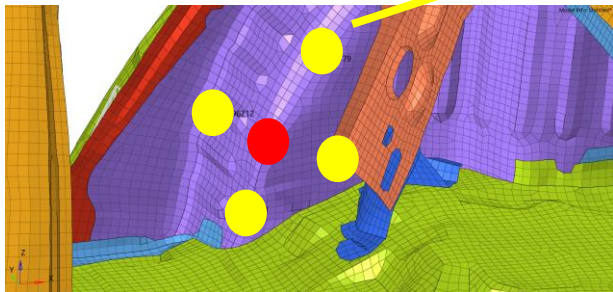
Loads

Stress

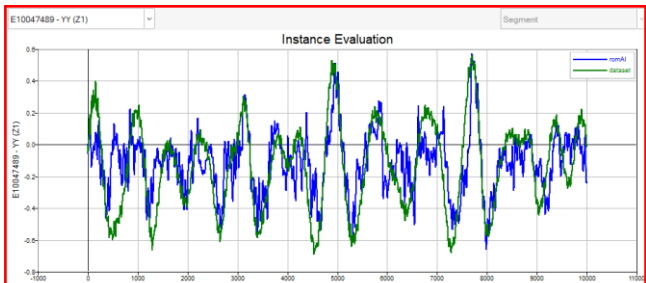


基于romAI的应力降阶建模

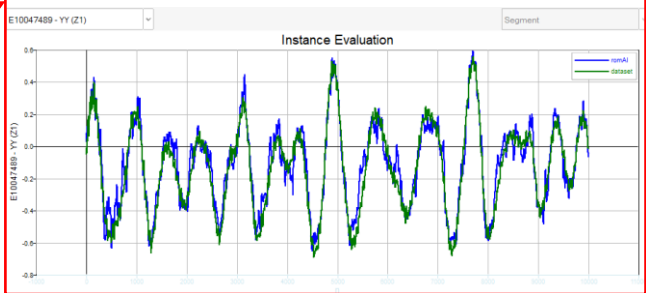
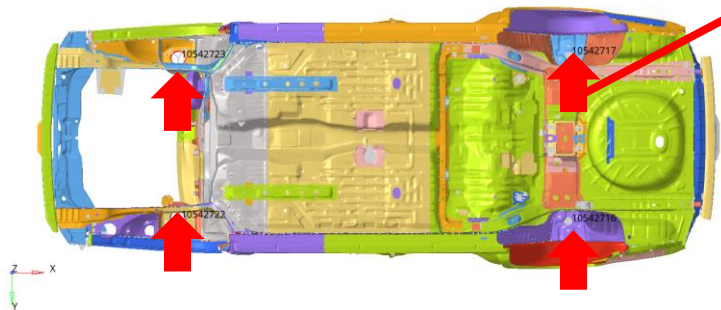
在车身四个减振塔加载xyz三方向实测加速度，通过romAI获得车身后轮毂包附近局部应力，如右侧曲线所示无论是关注位置附近还是四个加载点加速度都可以比较好的预测局部应力。



关注单元附近节点加速度



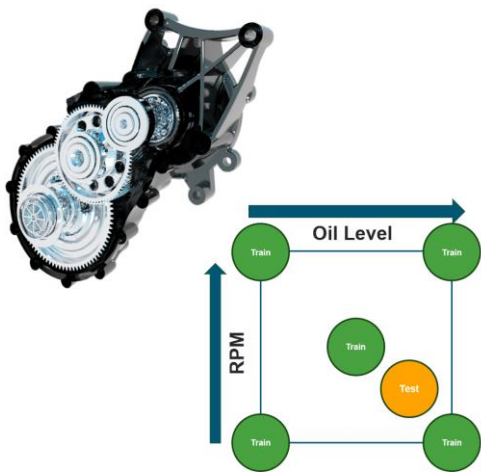
四个减振塔Z向加速度



四个减振塔xyz向加速度

romAI+CFD应用：齿轮箱搅油模型降阶

- 训练样本来自nanoFluidX（基于SPH算法）齿轮箱搅油模型，共计算5个瞬态工况作为训练样本和一个瞬态工况作为验证样本。每个工况须采用2块GPU计算8小时。
- romAI的2个输入参数：输入轴转速和润滑油体积；1个输出参数和状态变量：齿轮表面的平均对流换热系数HTC。

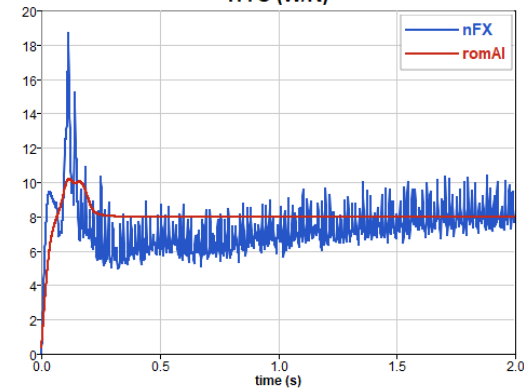
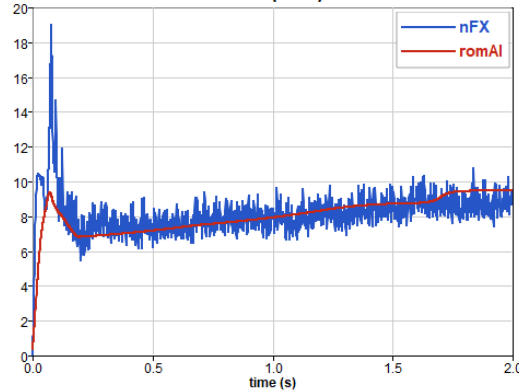
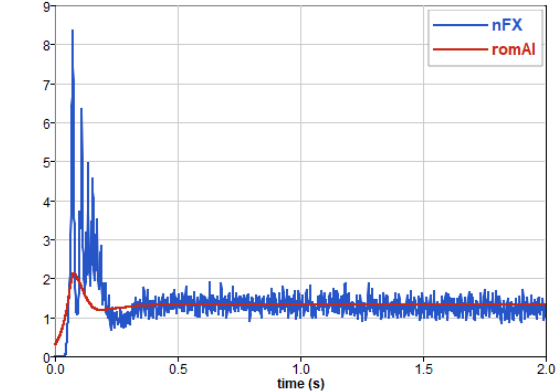
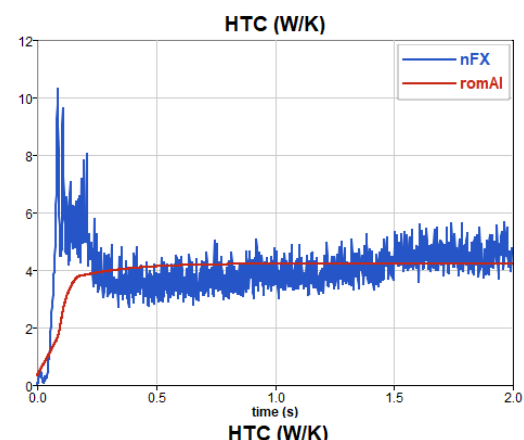
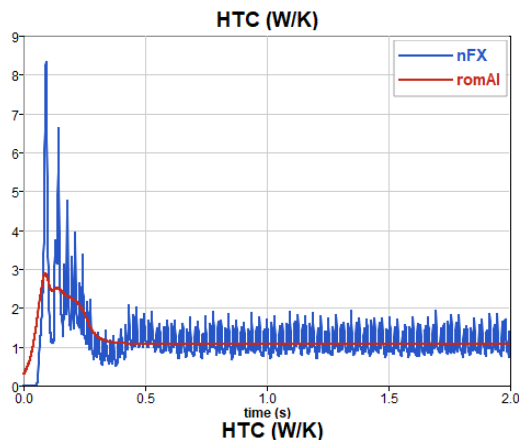
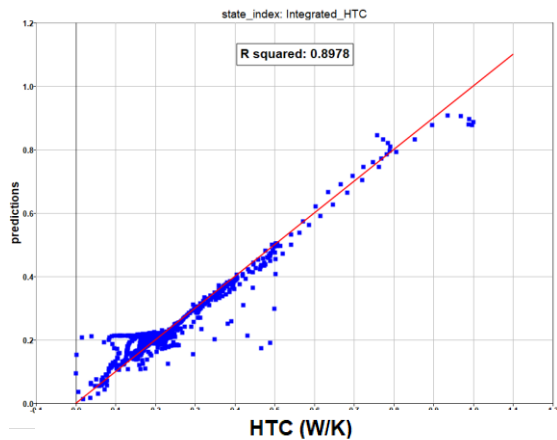


nanoFluidX仿真生成训练样本



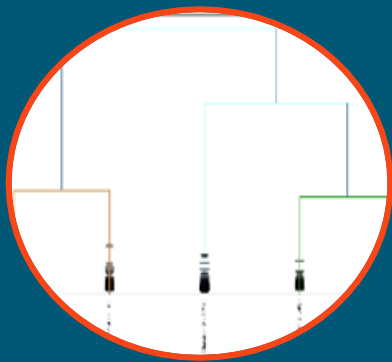
齿轮箱搅油瞬态动画

romAI+CFD应用：齿轮箱动态ROM的精度验证

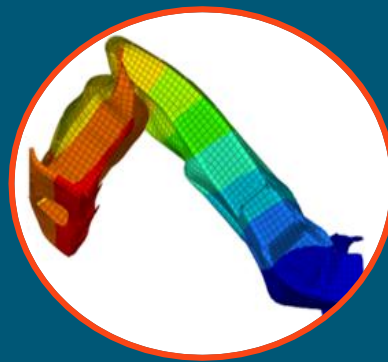


ExpertAI: 聚类分析与CAE的结合

专家确定模式

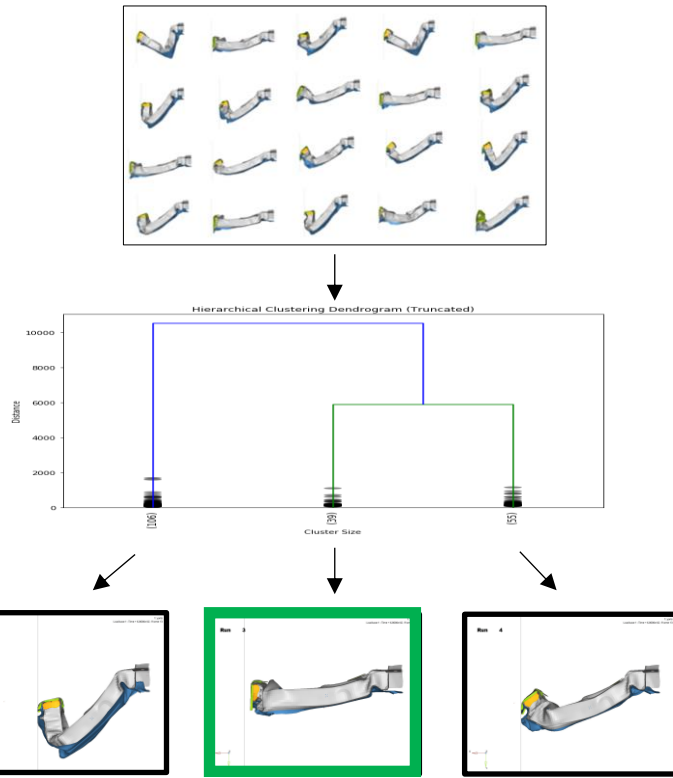
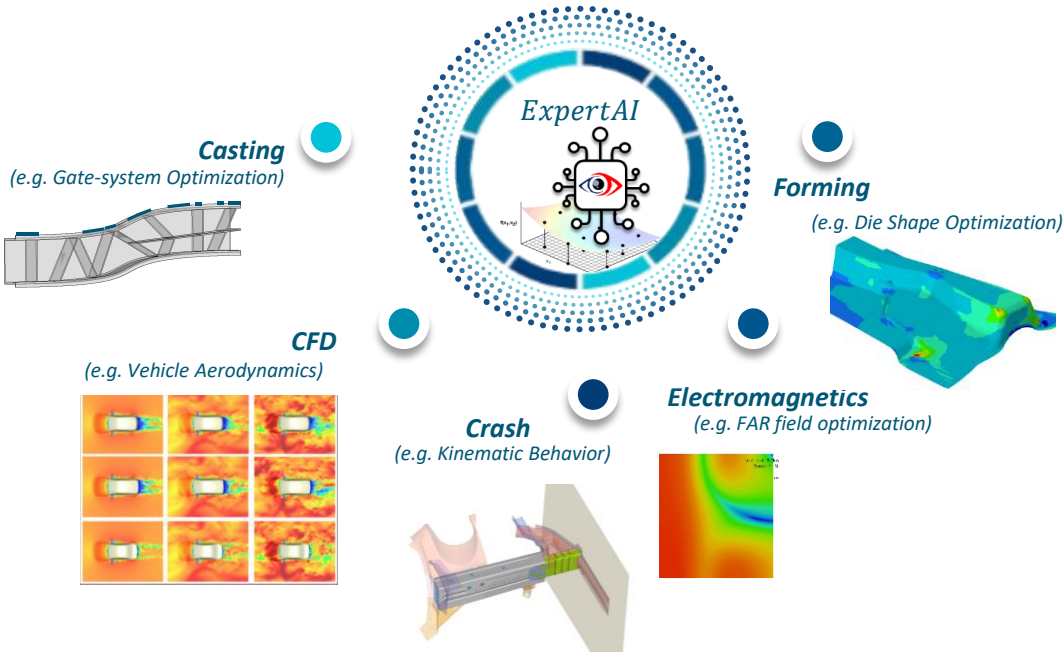


优化中强制执行专家偏好



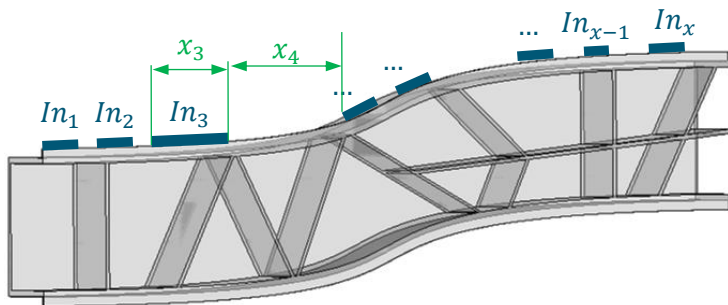
ExpertAI - 基于机器学习的模式聚类与优化

性能指标难以量化，模式识别，行业专家模拟



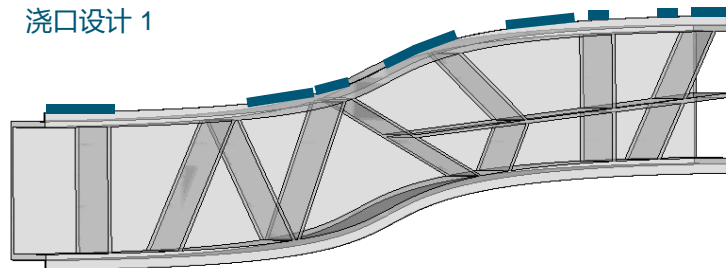
案例：铸造过程优化

如何优化浇注入口参数，获得符合预期的流动模式？

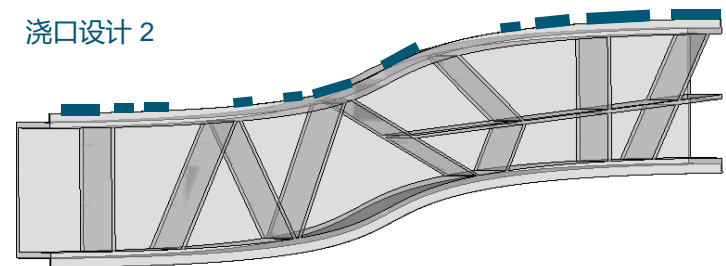


- 入口尺寸
- 入口位置
- 入口速度

▪ 浇口设计 1

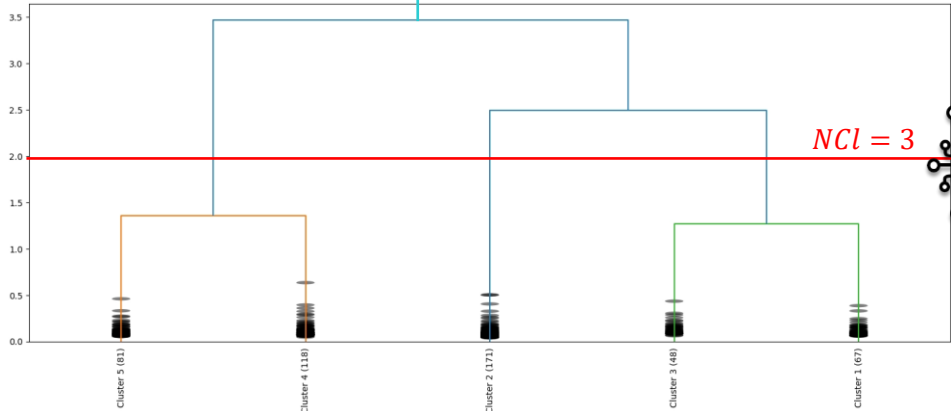
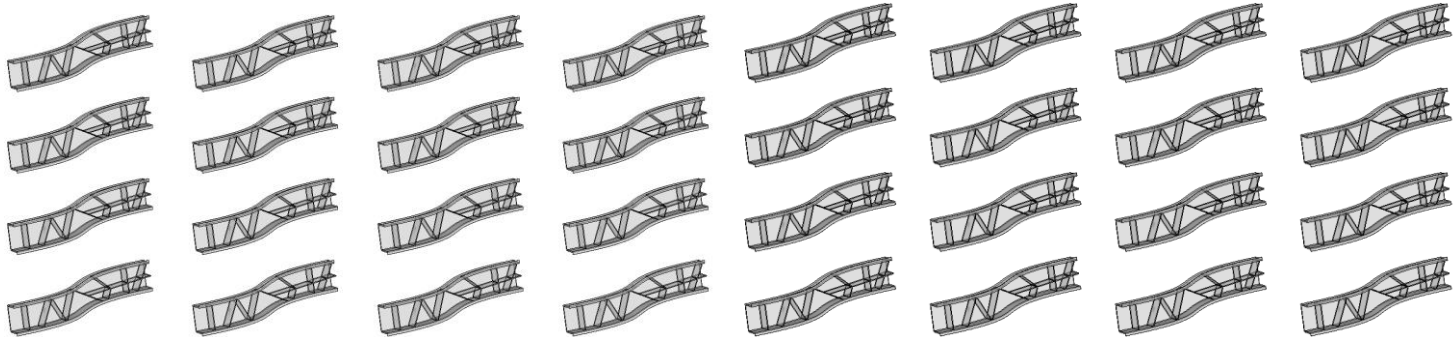


▪ 浇口设计 2



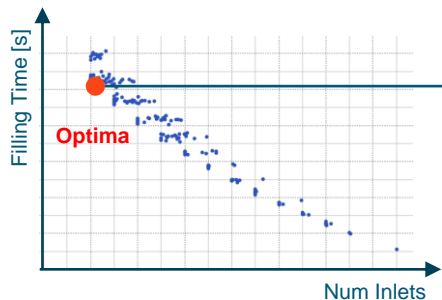
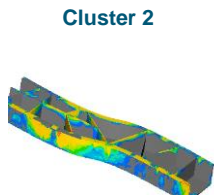
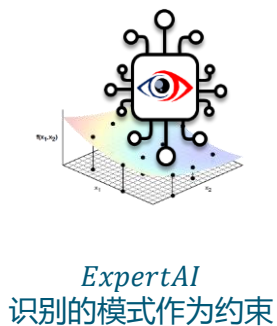
聚类:

基于DOE的, 不同变量组合的设计:

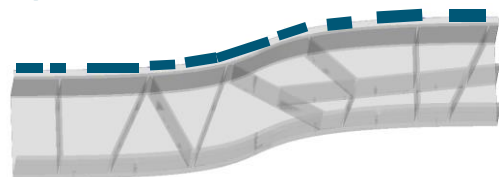


聚类识别行为模式

基于ExpertAI的铸造过程优化

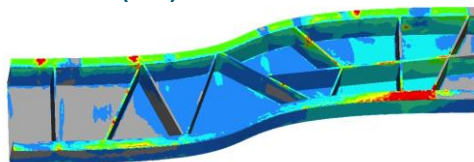


▪ **Optima_{d127}: 20 Inlets**



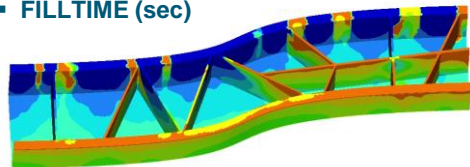
流动均匀性

▪ **Max Vel (m/s)**



减少金属液体对入口的冲击

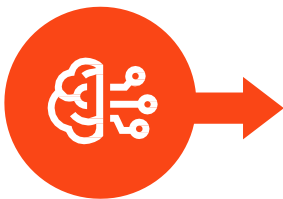
▪ **FILLTIME (sec)**



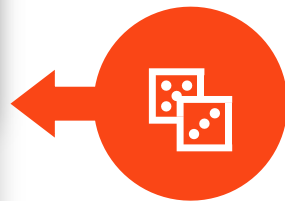
控制填充时间使得局部不出现过热

AI与仿真相互成就未来

设计/开发过程的效率
持续提升?



用于人工智能的数据
从哪里来?



AI 助力仿真:

使用人工智能, 加速、优化和增强仿真能力。

仿真助力 AI:

利用仿真生成数据, 作为人工智能模型的训练和测试。



THANK YOU

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