



# Marc磨损分析解决方案

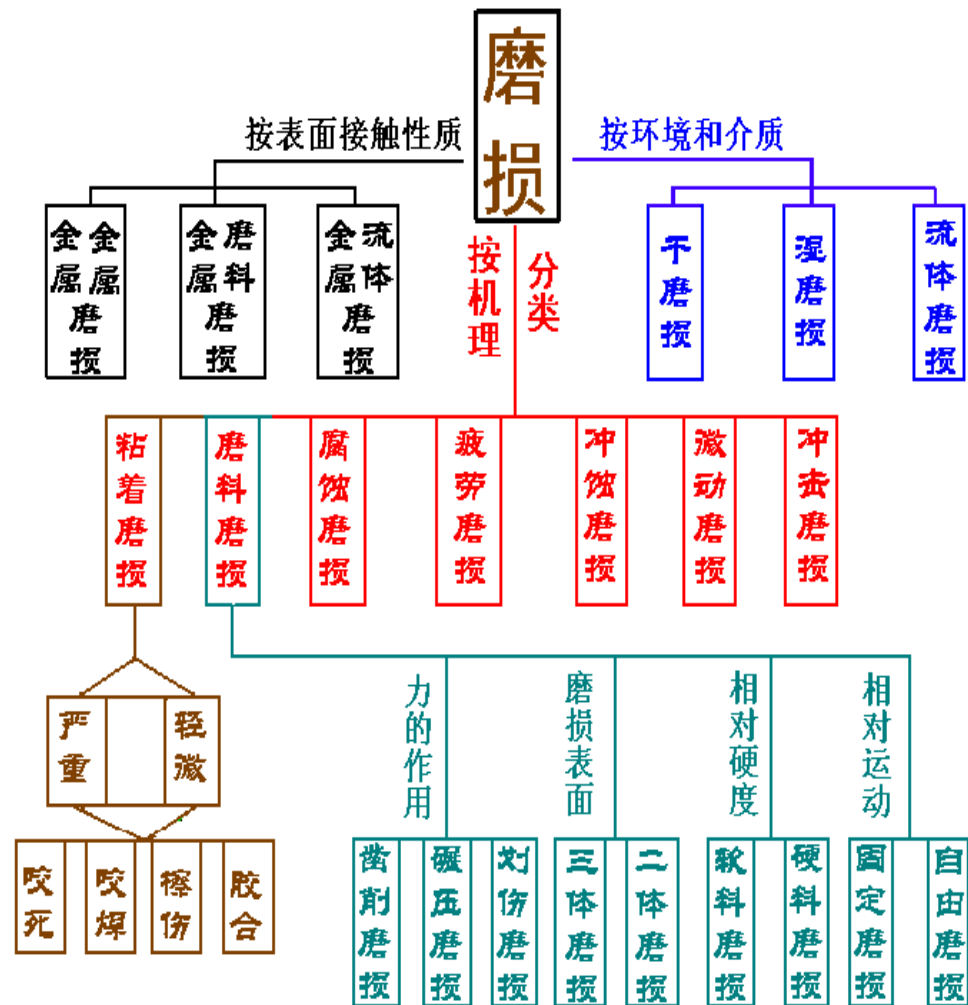
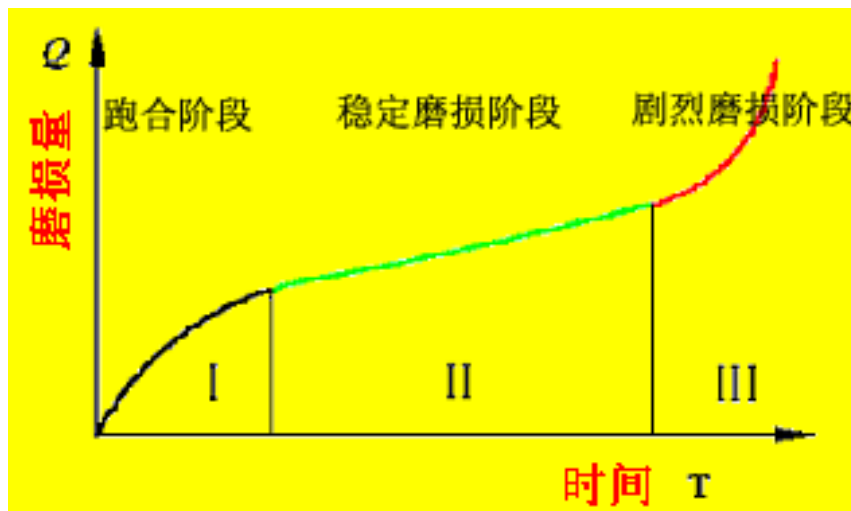
2019年12月23日

# 主要内容

- 1、磨损机理
- 2、磨损分析应用领域
- 3、磨损数值模型
- 4、磨损参数的获取
- 5、应用案例
- 6、建议软件配置

# 机械磨损机理

- 粗糙表面材料的变形及移除
- 材料的刨除 (Plowing或Ploughing)
- 脱层
- 粘接撕除
- 研磨
- 微动磨损
- 固体粒子撞击



# 磨损分析应用领域

- 存在磨损现象的领域:

- 刹车片
- 与运动部件接触的密封件
- 切削
- 滚压
- 发动机
- 轴承
- 齿轮
- 线性结构滑移
- 轮胎
- 骨关节

- 存在的问题分类:

- 适合中等程度的磨损

$M < 0.4$

磨损率 < 临界值

极度光滑表面 - 抛光

Debris < 100 nm 直径

应用Archard 方程

- 剧烈的磨损

$M > 0.4$

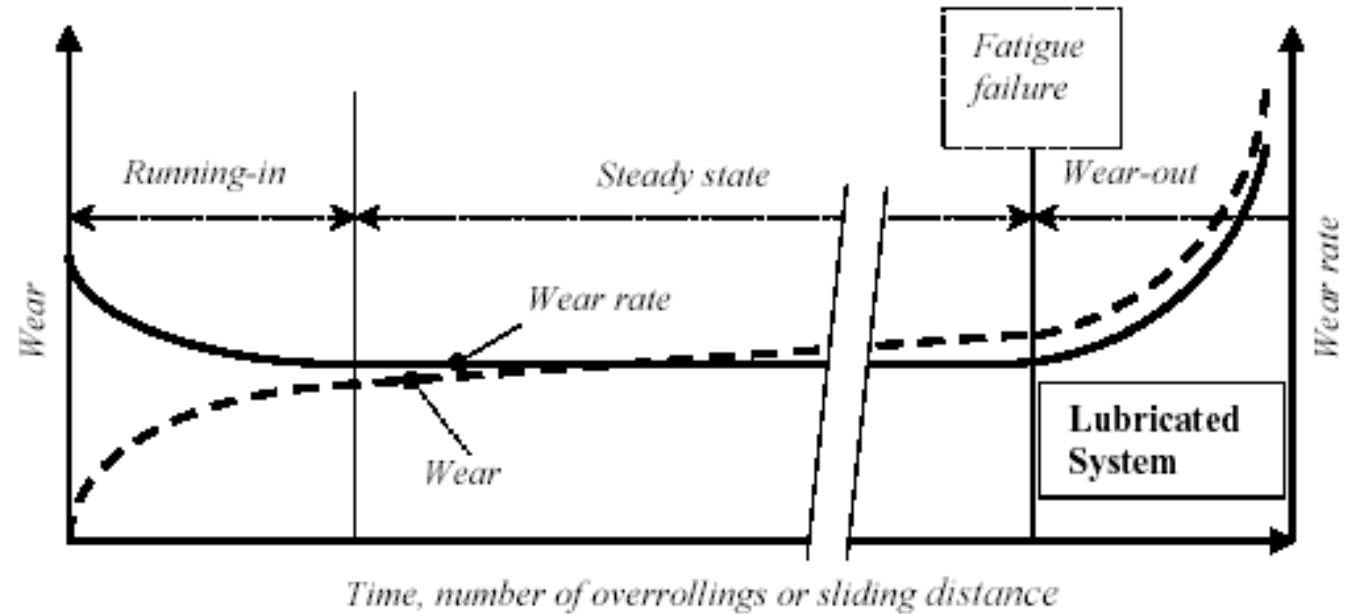
磨损率 > 临界值

粗糙, 深度撕裂表面

大的粗糙粒子大于 0.01 mm

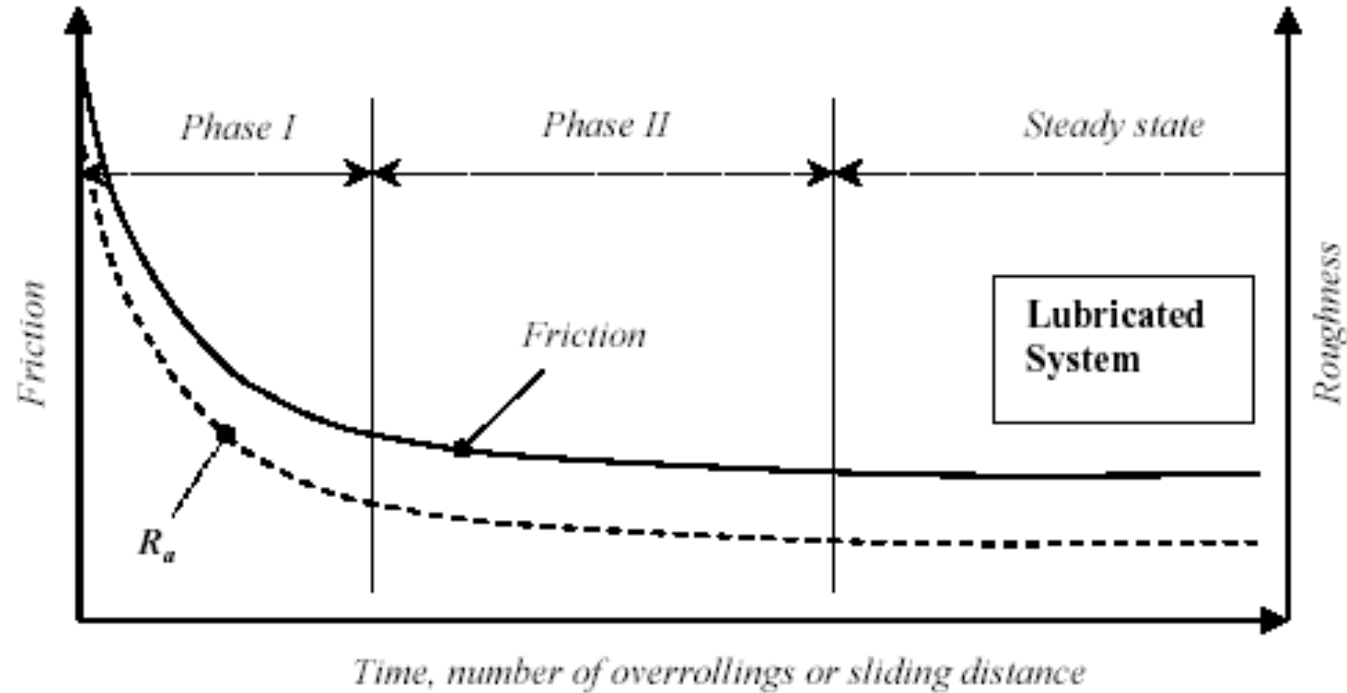
# 磨损现象

## 磨损和磨损率随时间或周期的变化



# 磨损现象

在恒定运行条件下，摩擦系数和粗糙度是时间的函数



# 磨损模型

- 常用磨损模型
  - Archard 方程
  - Archard 方程的修正
- 变形更新
- 几何更新

## Contact and Rubbing of Flat Surfaces

Show affiliations

[Archard, J. F.](#)

The interpretation of certain phenomena occurring at nominally flat surfaces in stationary or sliding contact is dependent on the assumed distribution of the real area of contact between the surfaces. Since there is little direct evidence on which to base an estimate of this distribution, the approach used is to set up a simple model and compare the deduced theory (e.g., the deduced dependence of the experimental observables on the load) with the experimental evidence. The main conclusions are as follows. (a) The electrical contact resistance depends on the model used to represent the surfaces; the most realistic model is one in which increasing the load increases both the number and size of the contact areas. (b) In general, mechanical wear should also depend on the model. However, in wear experiments showing the simplest behavior, the wear rate is proportional to the load, and these results can be explained by assuming removal of lumps at contact areas formed by plastic deformation; moreover, this particular deduction is independent of the assumed model. This suggests that a basic assumption of previous theories, that increasing the load increases the number of contacts without affecting their average size, is redundant.

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**Pub Date:** August 1953

**DOI:** [10.1063/1.1721448](https://doi.org/10.1063/1.1721448) 

**Bibcode:** [1953JAP...24..981A](#) 

# 经典的 Archard 磨损模型

- $W = K * F * G_t / H$

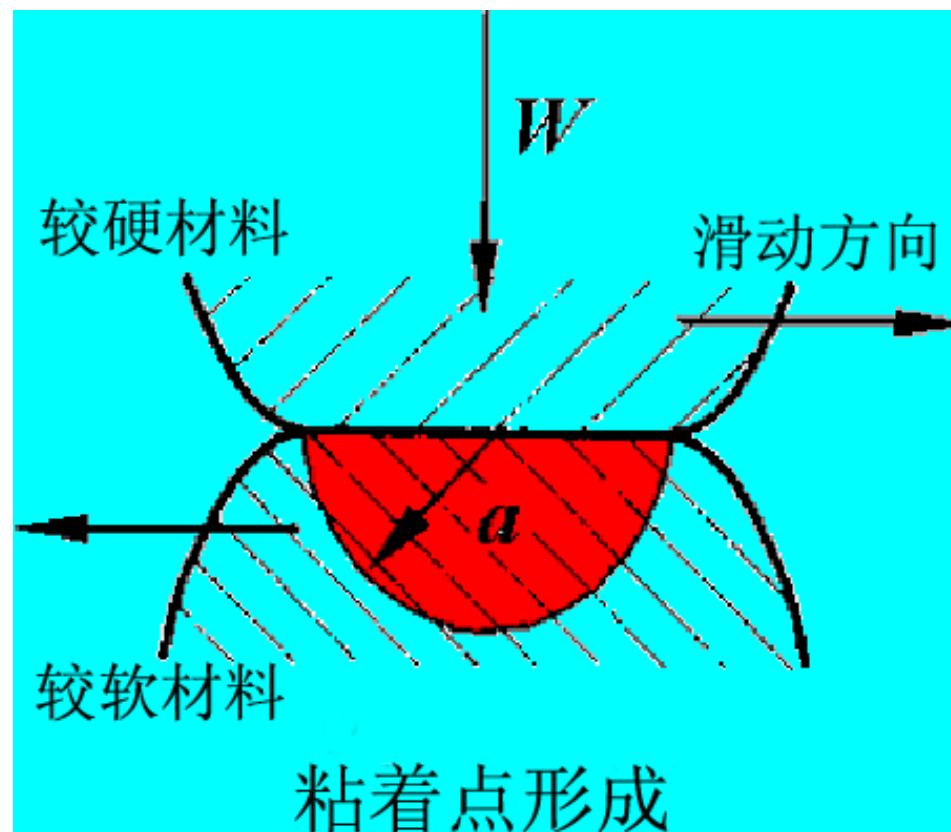
W: 磨损量

K: 磨损系数

F: 法向力

$G_t$ : 滑移距离

H: 硬度





# 磨损模型

- $Du_w/Dt = A \sigma_n V_s$
- $Du_w/Dt = A \sigma_n^m V_s^n$  – Bayer指数形式
- $Du_w/Dt = A \sigma_n^m V_s^n \exp^{-B/T}$  – 带热激活能的Bayer指数形式
- $Du_w/Dt = A \sigma_n V_s \exp^{-Q/RT}$
- $Du_w/Dt = A(T) \sigma_n V_s$  – 材料参数可以与温度相关

$\sigma_n$  – 法向应力

$V_s$  – 滑移速度

$R$  – 气体常数

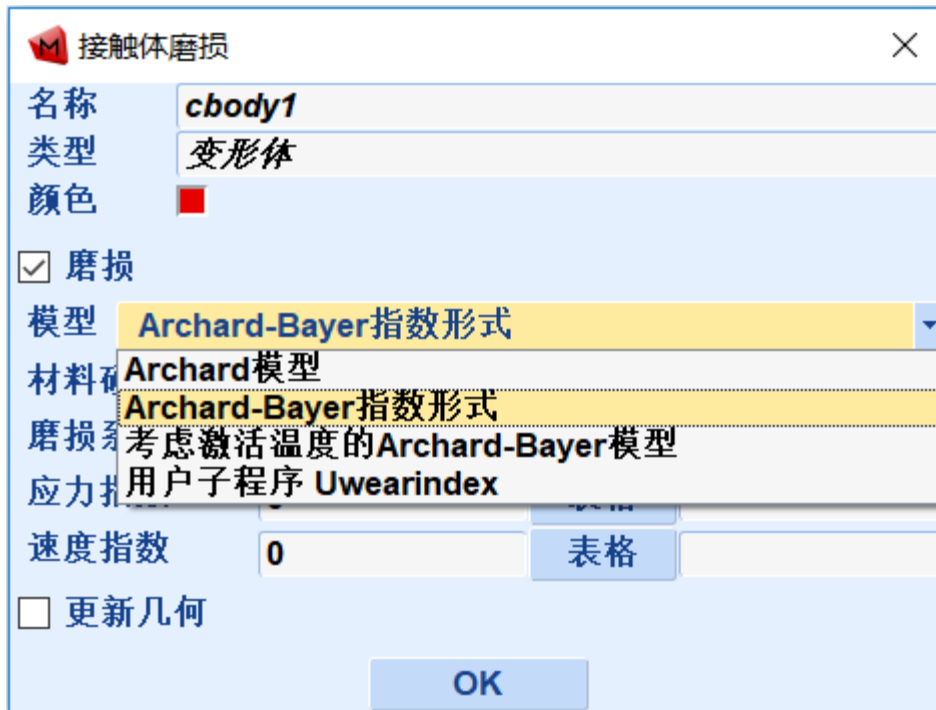
$Q$  – 激活能

$T$  – 绝对温度

注：  $Du_w/Dt$  为法向磨损变化率

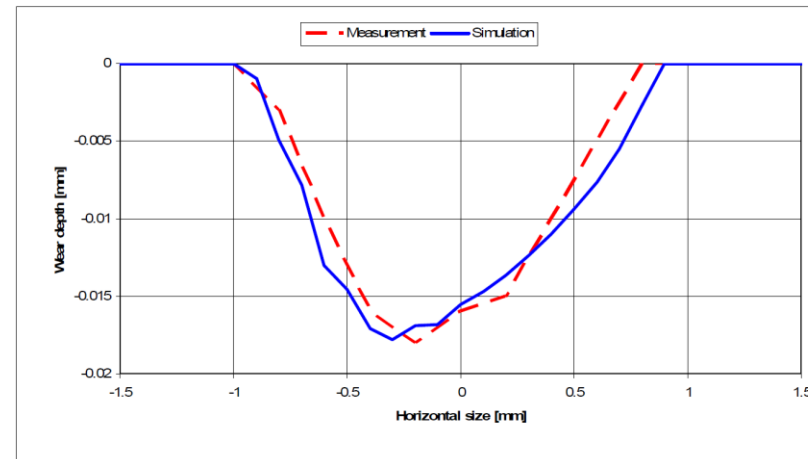
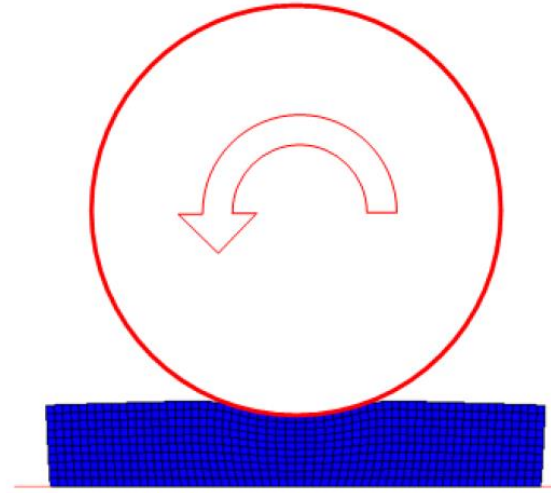
# 磨损模型的选择及参数定义菜单

- 在前处理接触体定义菜单里面可以选择磨损模型
- 也可以采用用户子程序定义用户的磨损模型



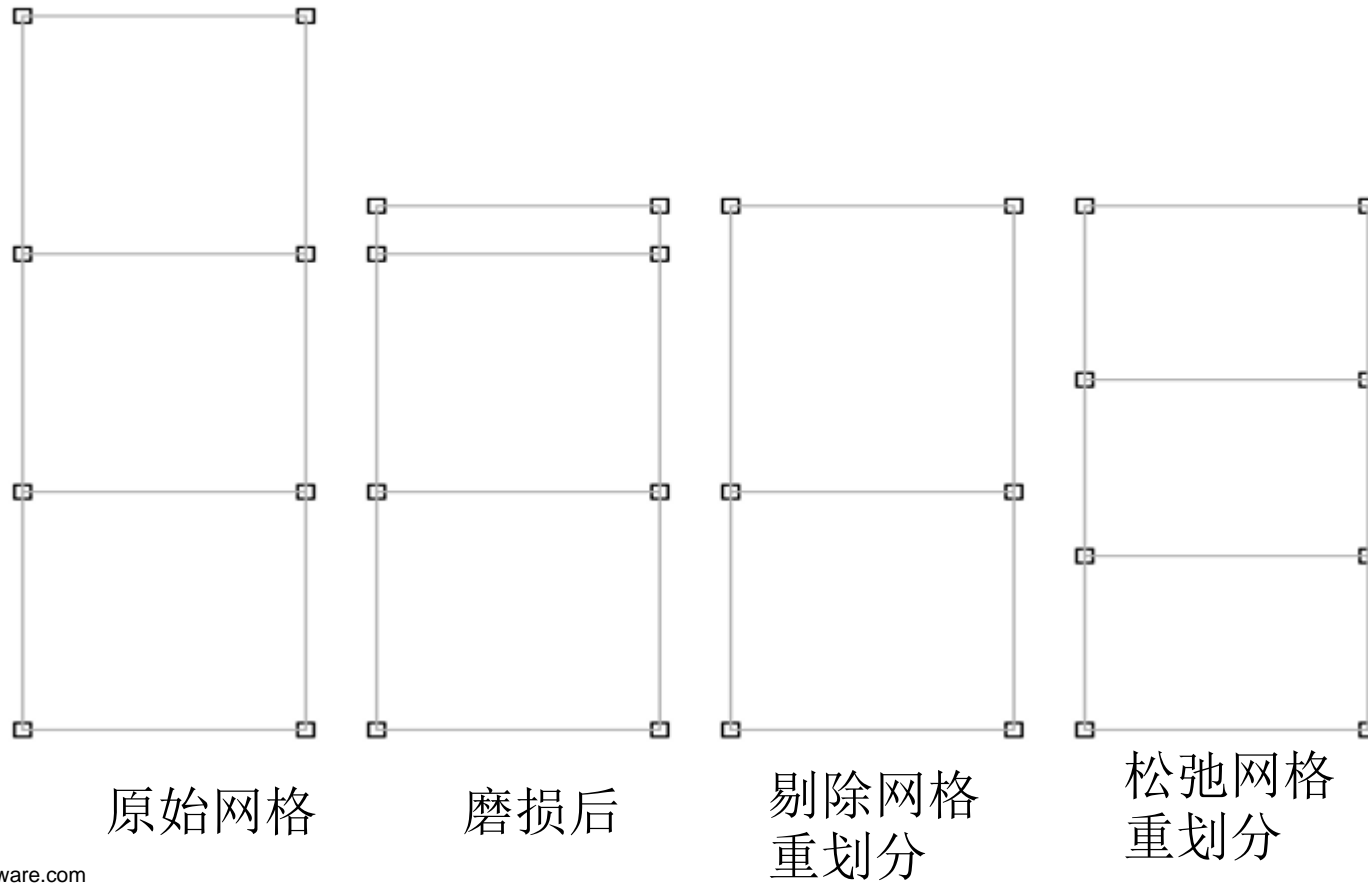
# 磨损模型材料参数的获取

- 磨损模型参数获取
  - 磨损试验是测定材料抵抗磨损能力的一种材料试验。通过这种试验可以比较材料的耐磨性优劣。[磨损试验](#)比常规的材料试验要复杂。首先需要考虑零部件的具体工作条件并确定磨损形式，然后选定合适的试验方法，以便使试验结果与实际结果较为吻合。磨损模型分为黏着磨损、磨粒磨损、冲蚀磨损、腐蚀磨损、微动磨损。
  - 测试标准：GB/T 12444
  - 来自ISO标准



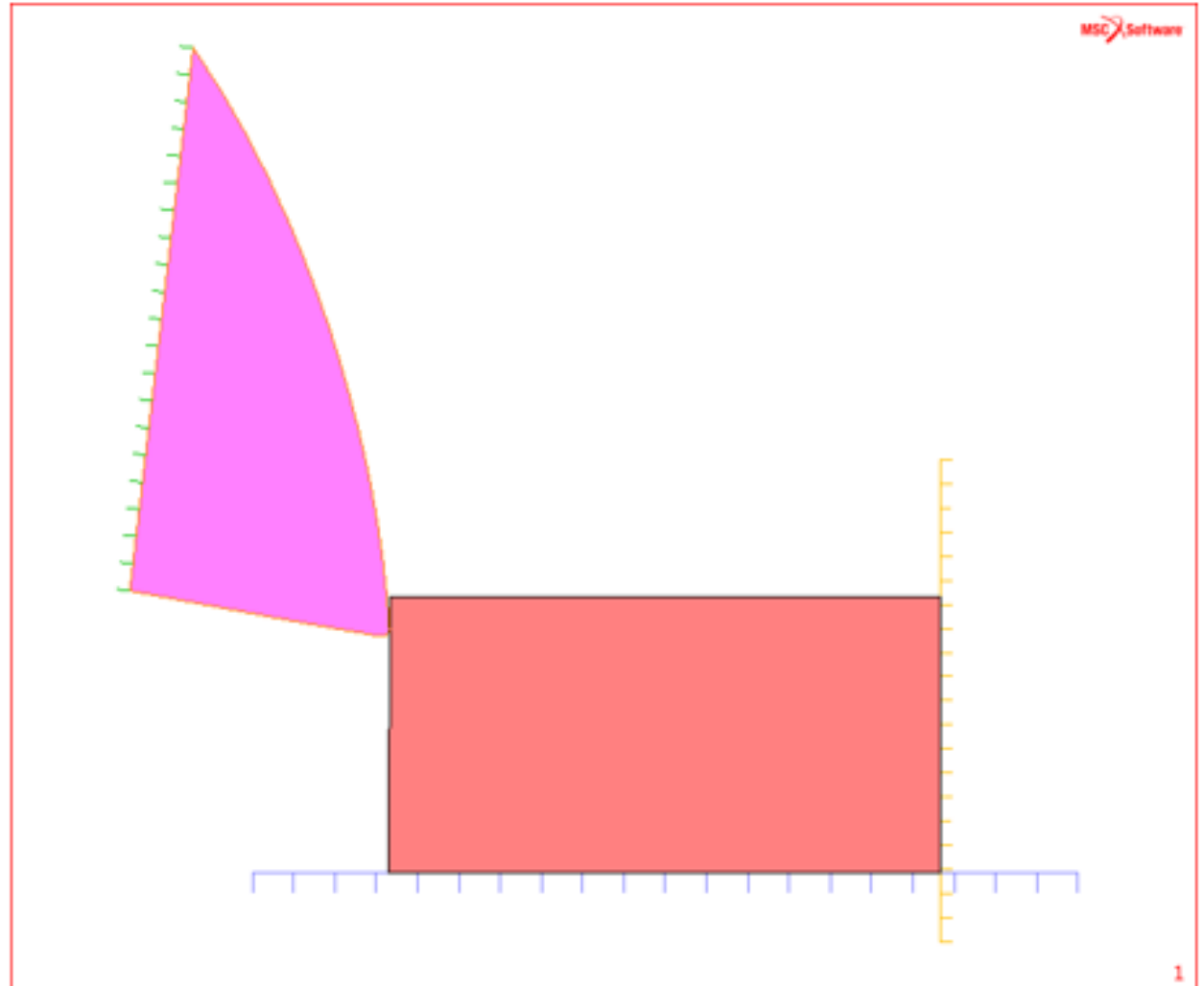
# 考虑磨损后的网格重划分

**Marc**有多种适合磨损分析的网格重划分方法

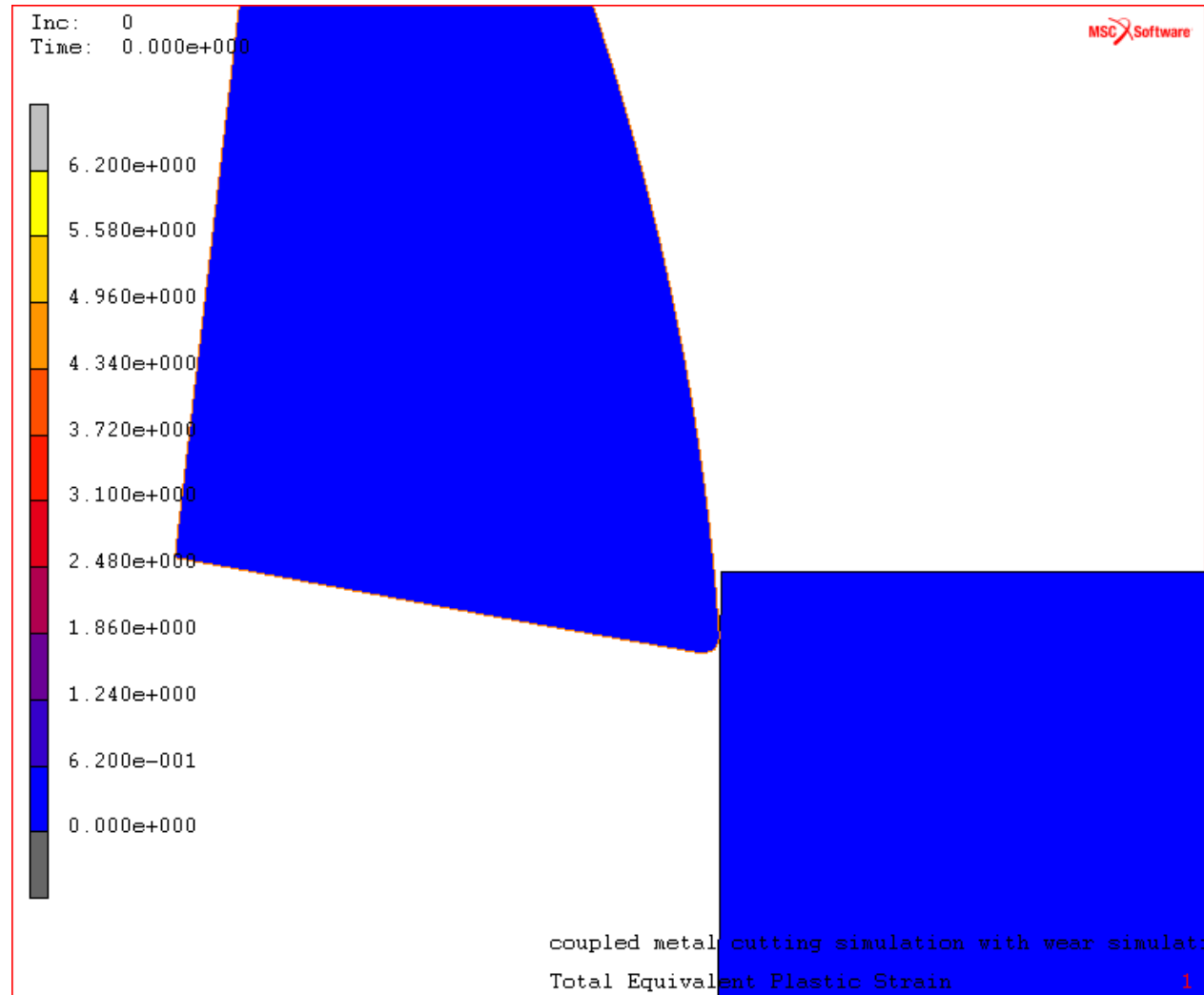


# 算例：切削 – 刀具的磨损

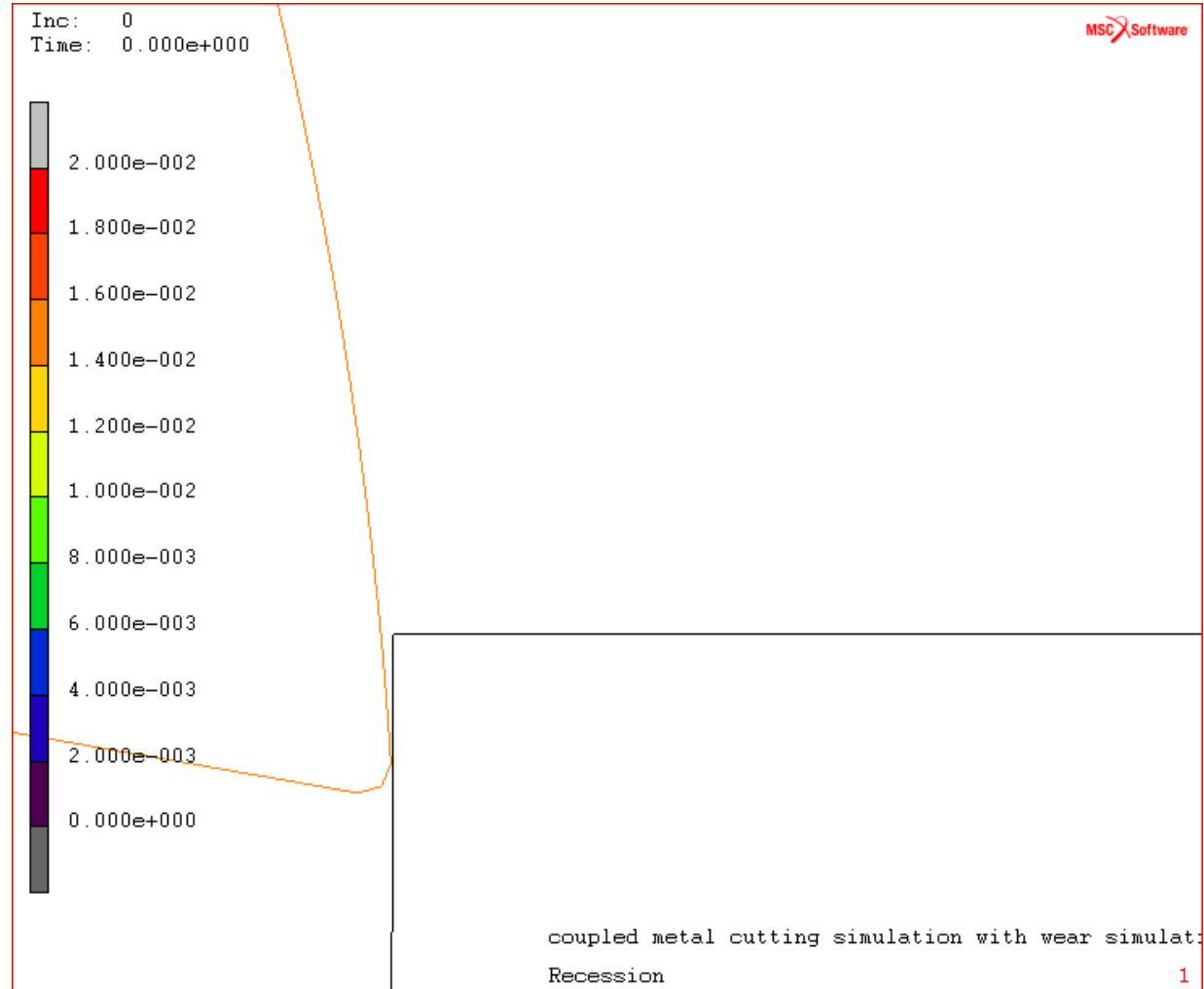
- 热机耦合分析
- 工件采用了网格重划分功能
- 采用**Archard** 模型



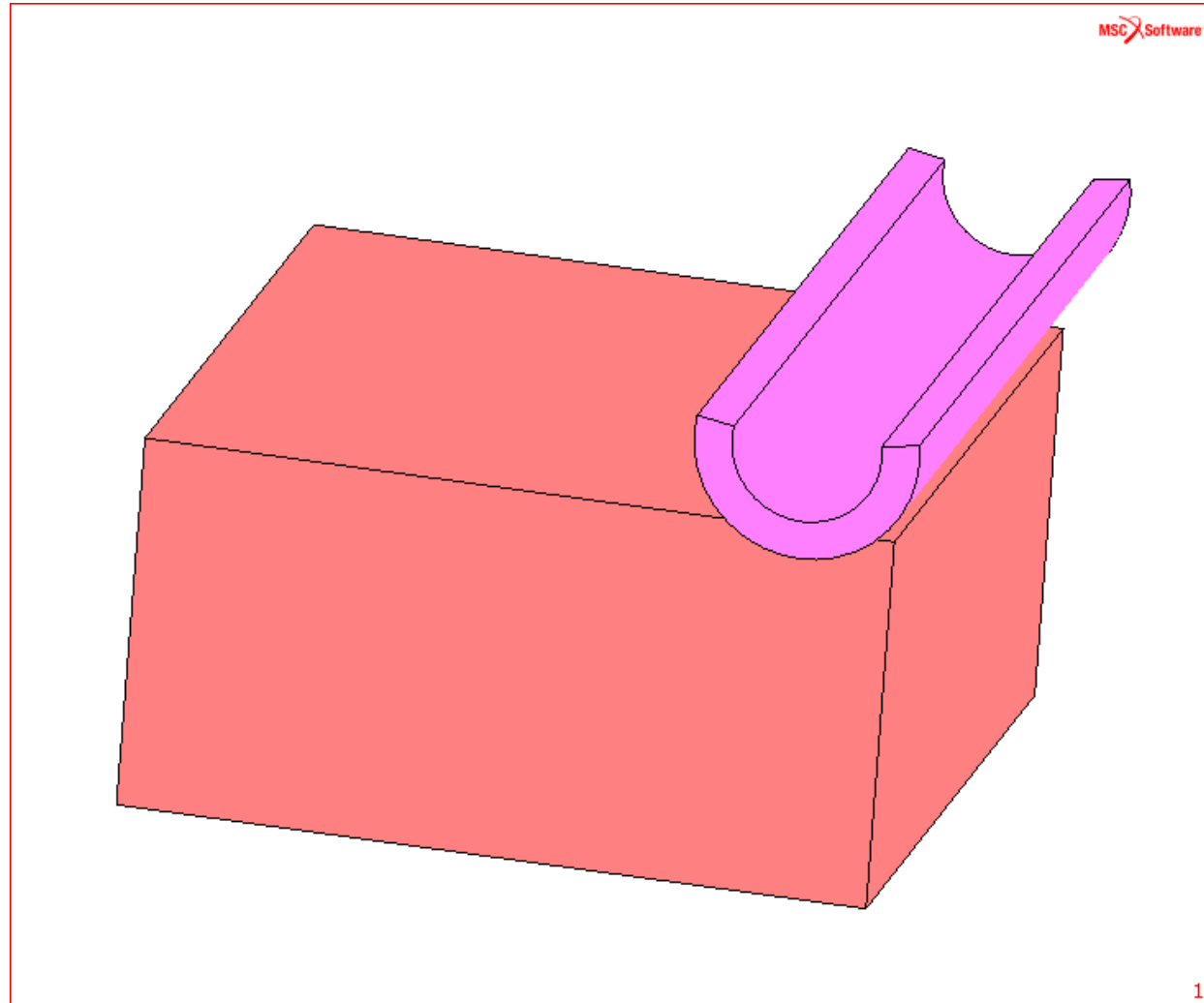
# 算例：切削 - 等效塑性应变云图动画



# 算例：切削 - 刀具的磨损矢量图

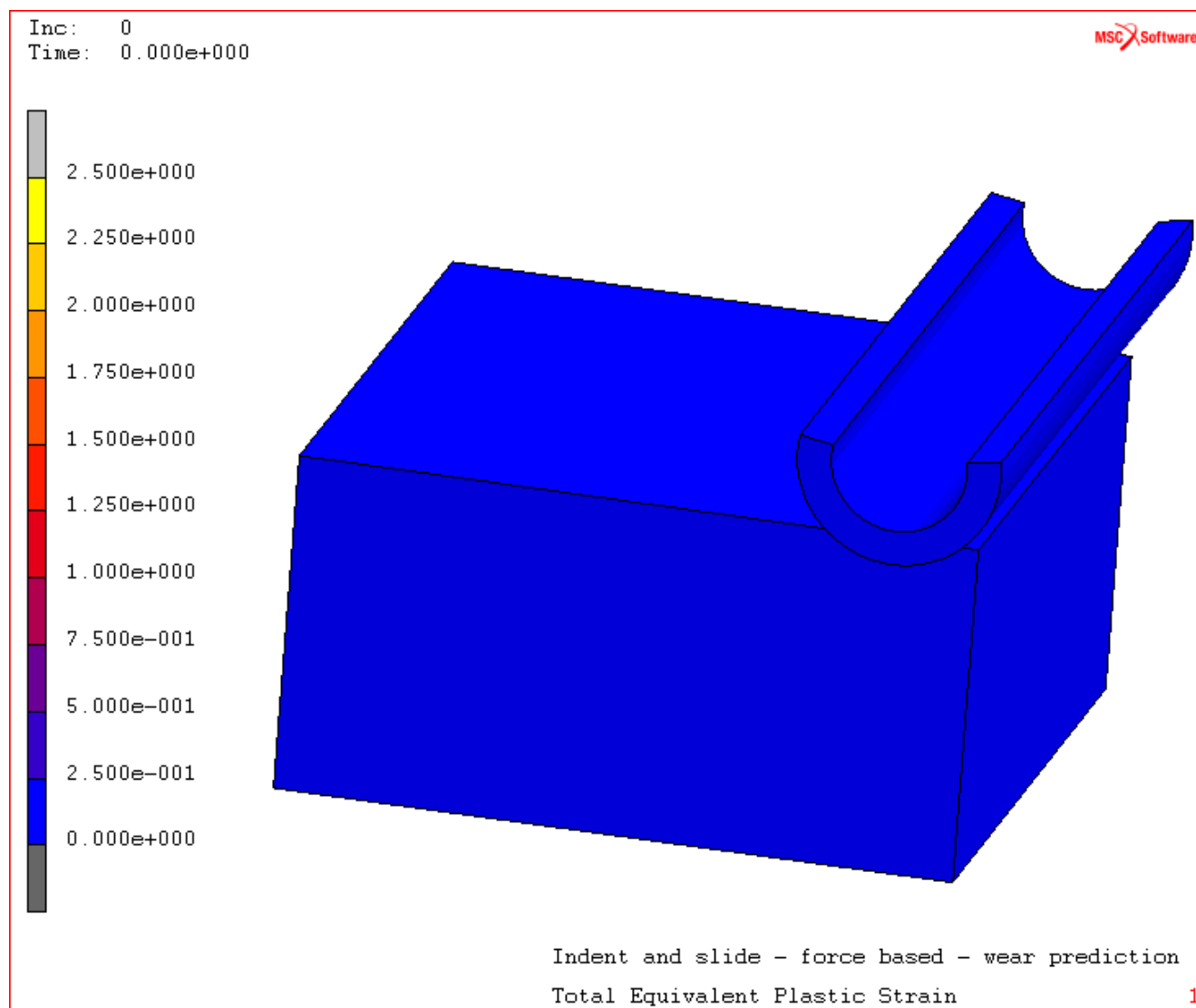


# 算例：材料加工中压头的磨损

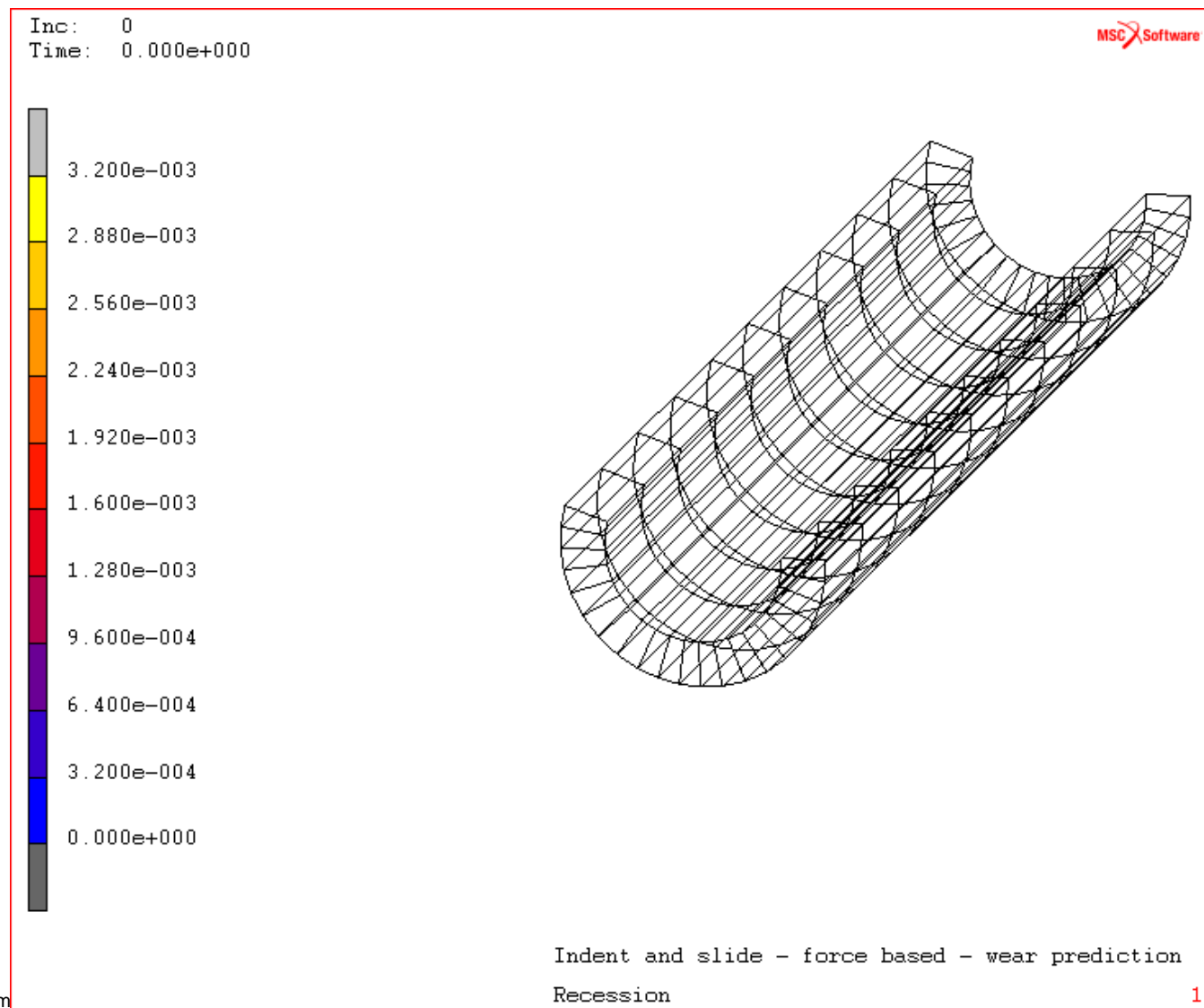




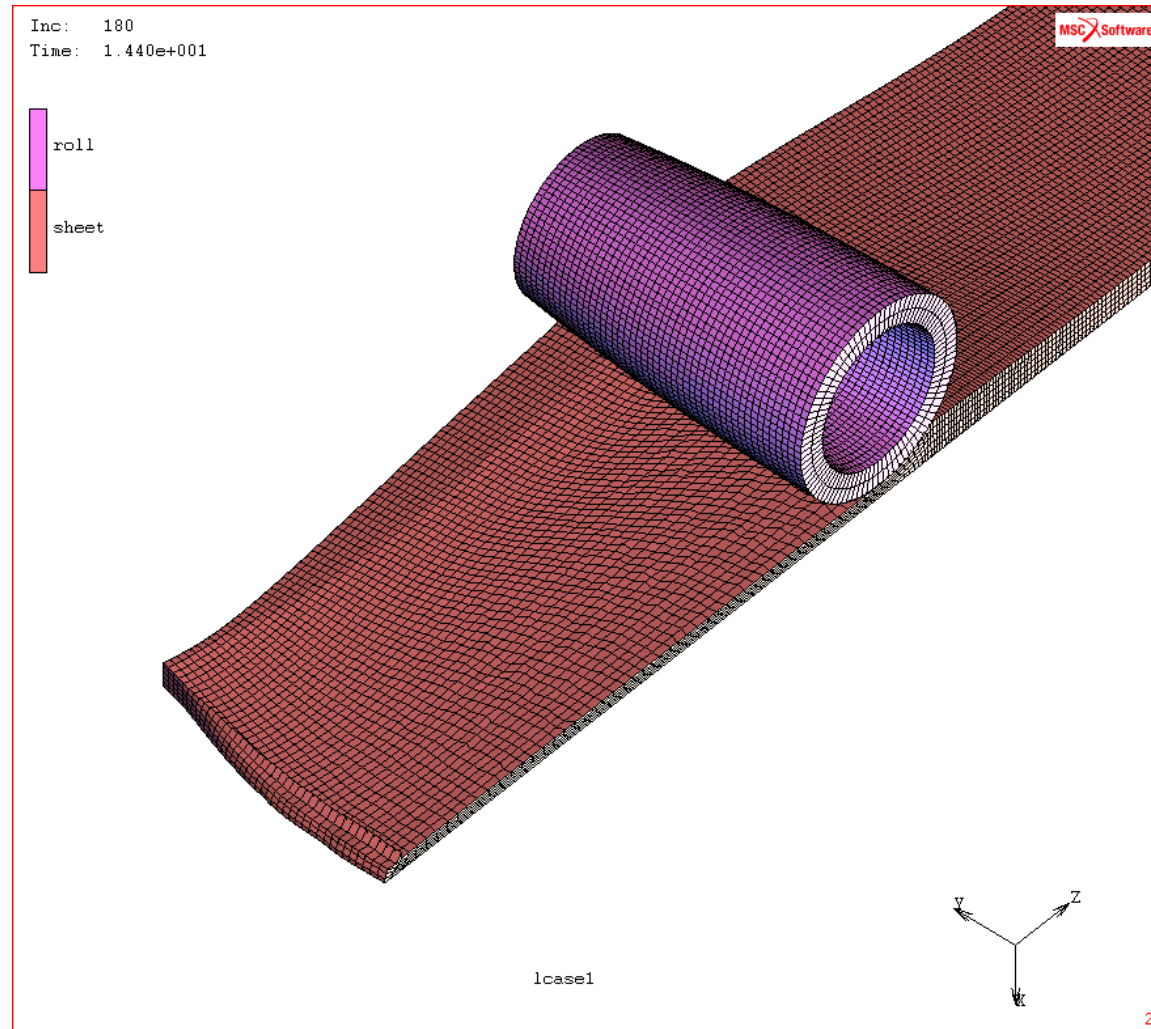
# 算例：工件的塑性应变云图动画



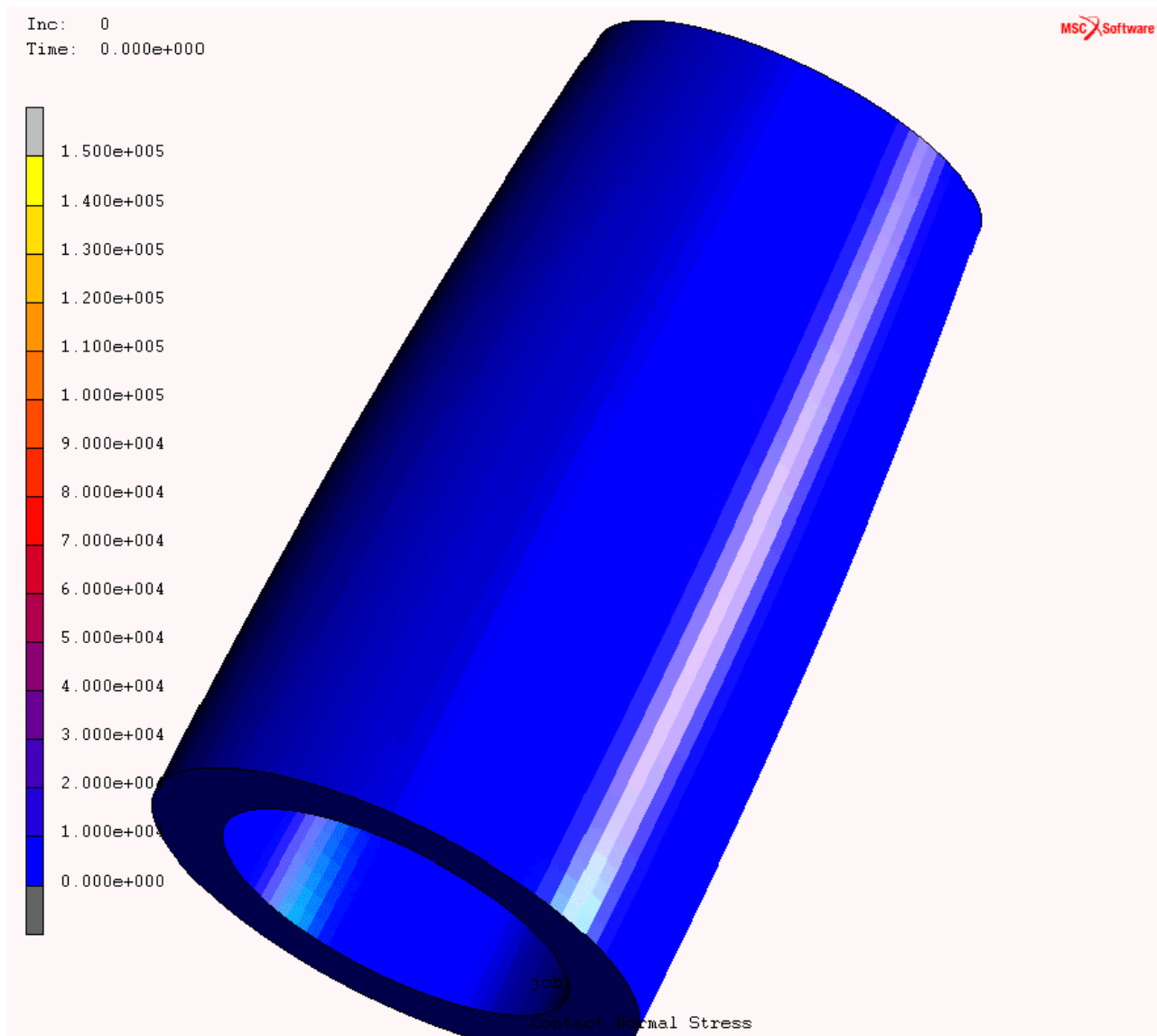
# 算例：模具磨损矢量显示



# 算例：梯形轧制轧辊磨损分析

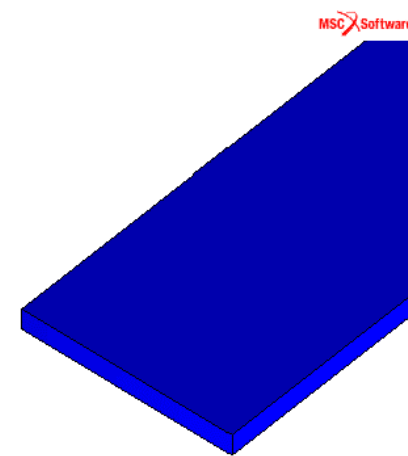
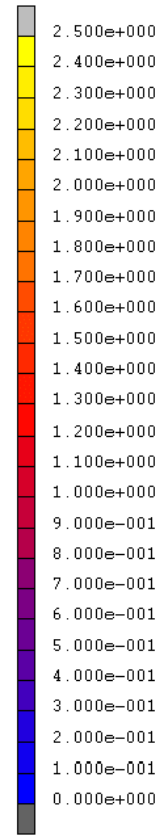


# 算例：轧辊的法向应力



# 算例：板件的塑性应变云图动画

Inc: 0  
Time: 0.000e+000

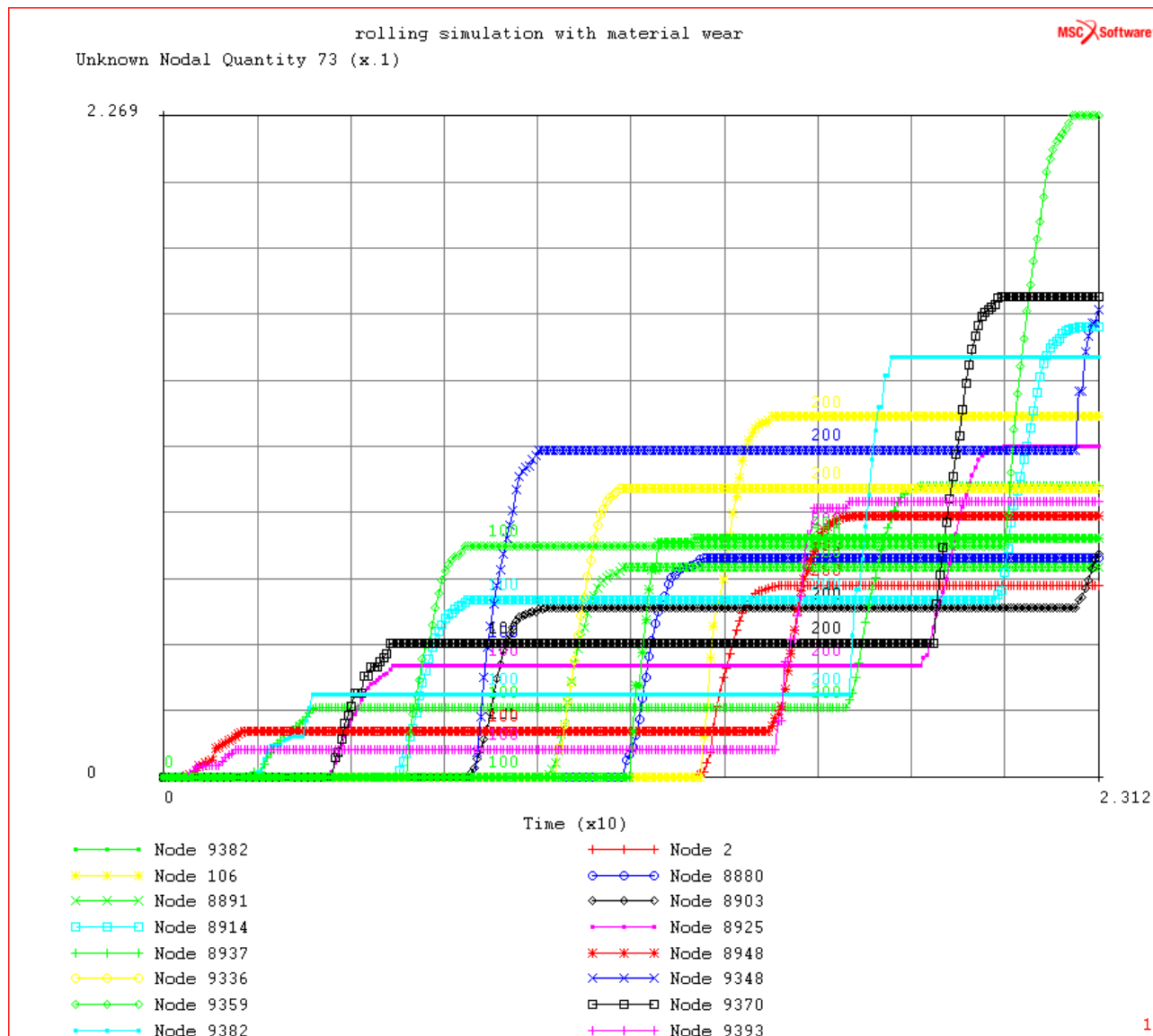


job1

Total Equivalent Plastic Strain

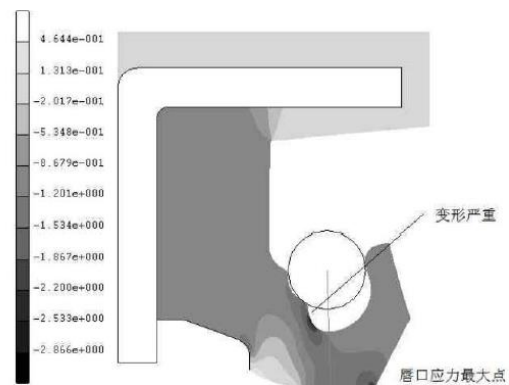
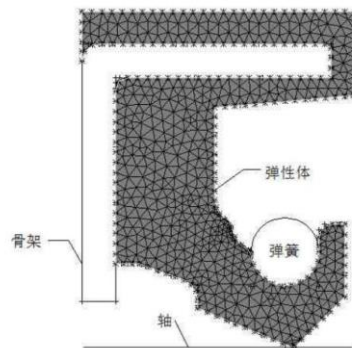
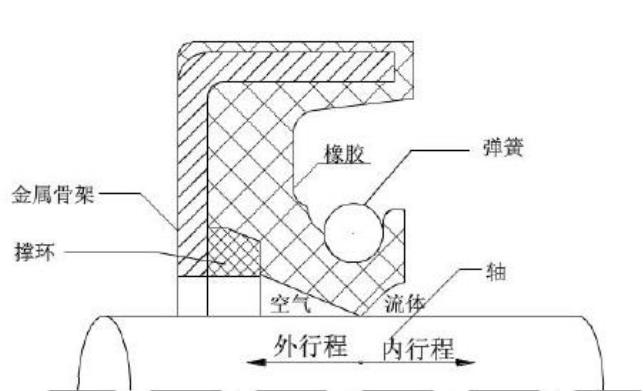
# 算例：轧辊磨损累积

- 节点在 **45** 度角的位置
- 第**5**节点在对称轴上
- 每个增量步转动**2°**

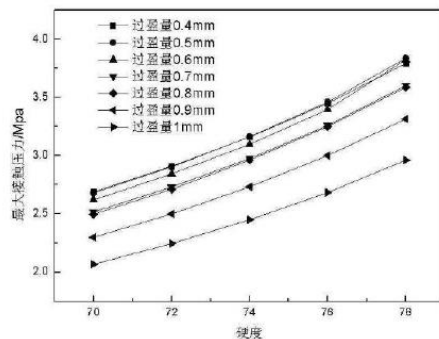


# 算例：橡胶密封件磨损

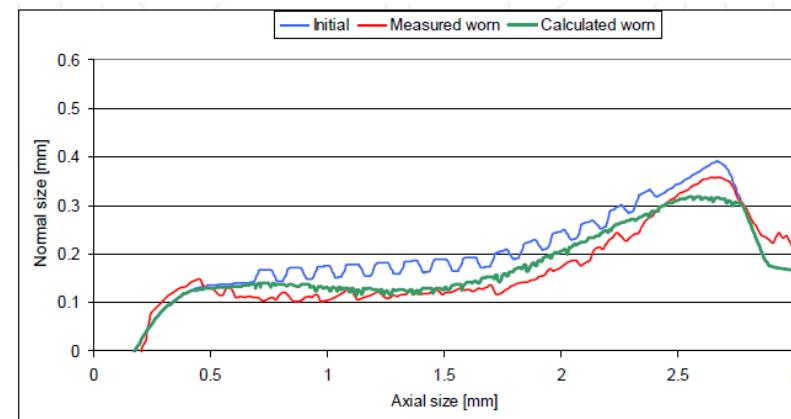
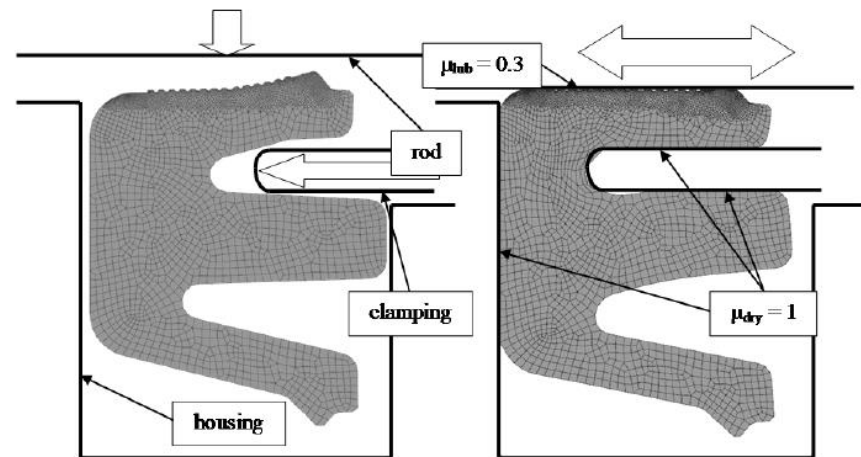
## • 密封性能分析



(b) 油侧压力 1Mpa 柯西应力图



## • 摩擦与磨损模型

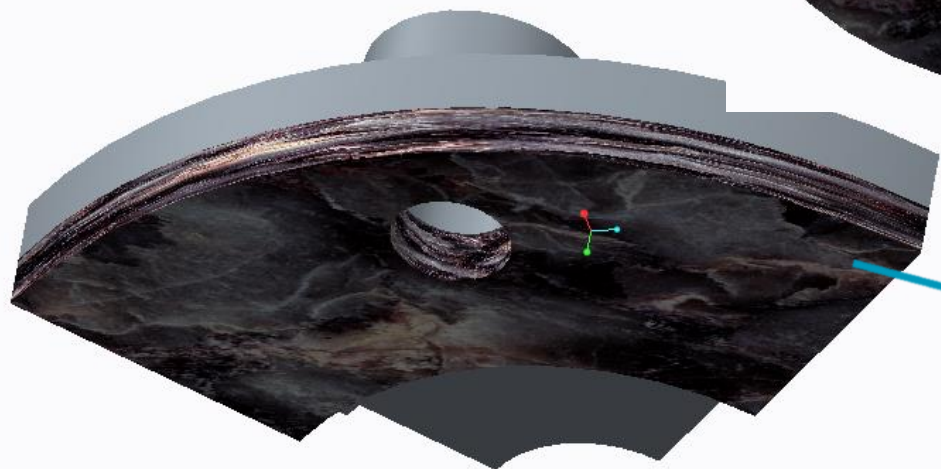
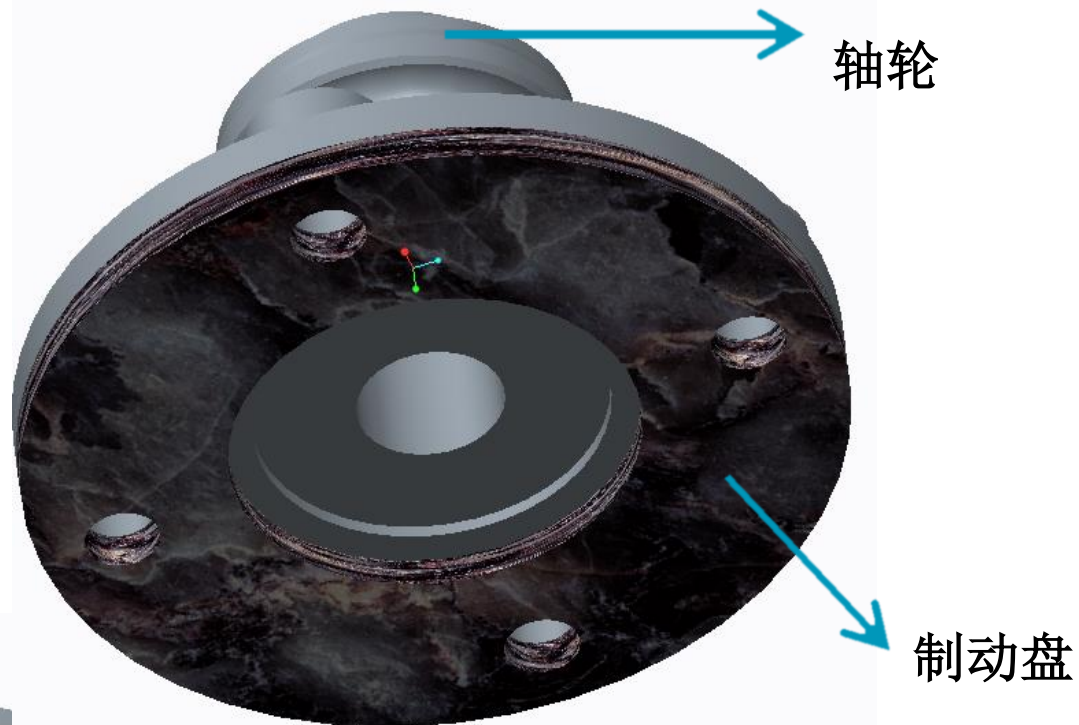




# 算例：轴承法兰结构微振磨损算例模型

- 模型组成

- 模型结构如右图所示，由轴轮和制动盘两部分构成
- 利用对称性，简化成1/4进行分析



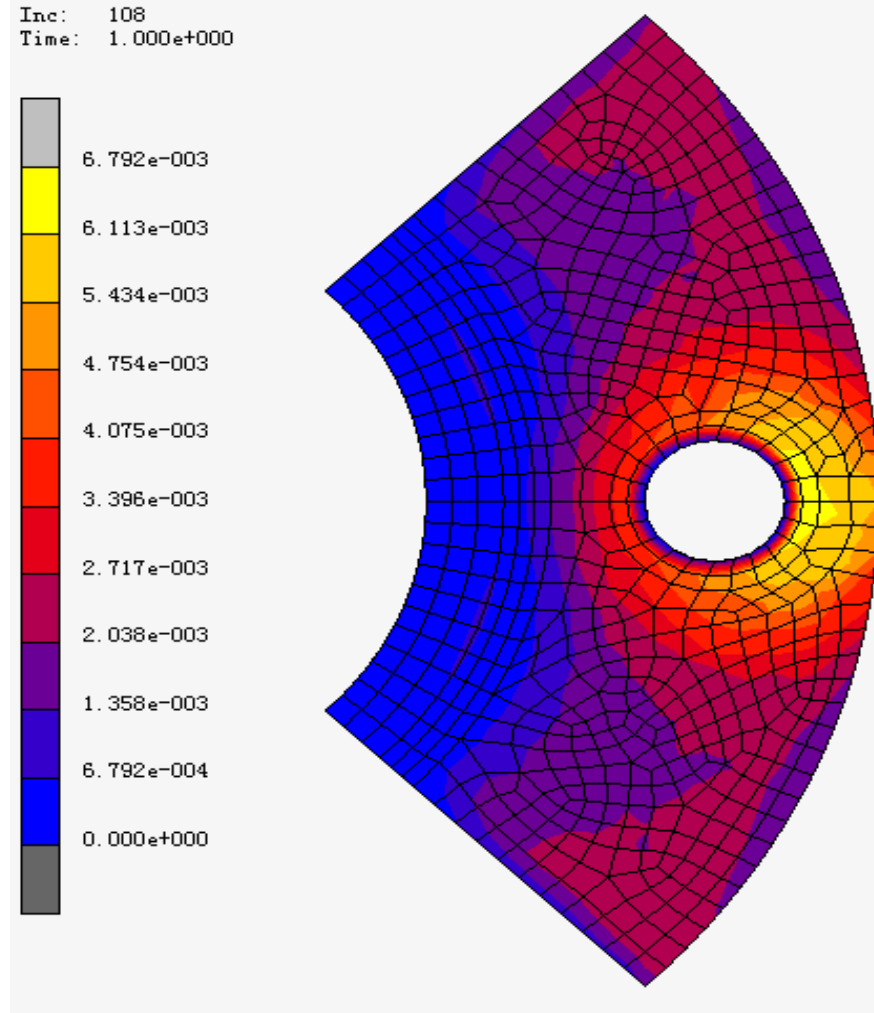
1/4模型的截面配合图



# 算例：轴承法兰微振磨损计算结果

可以看出：

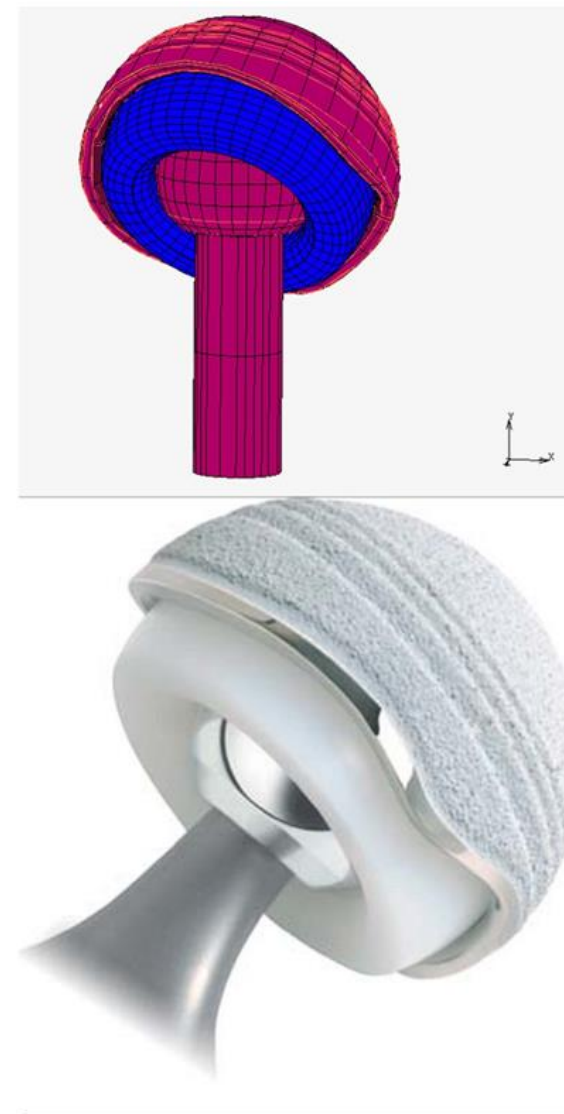
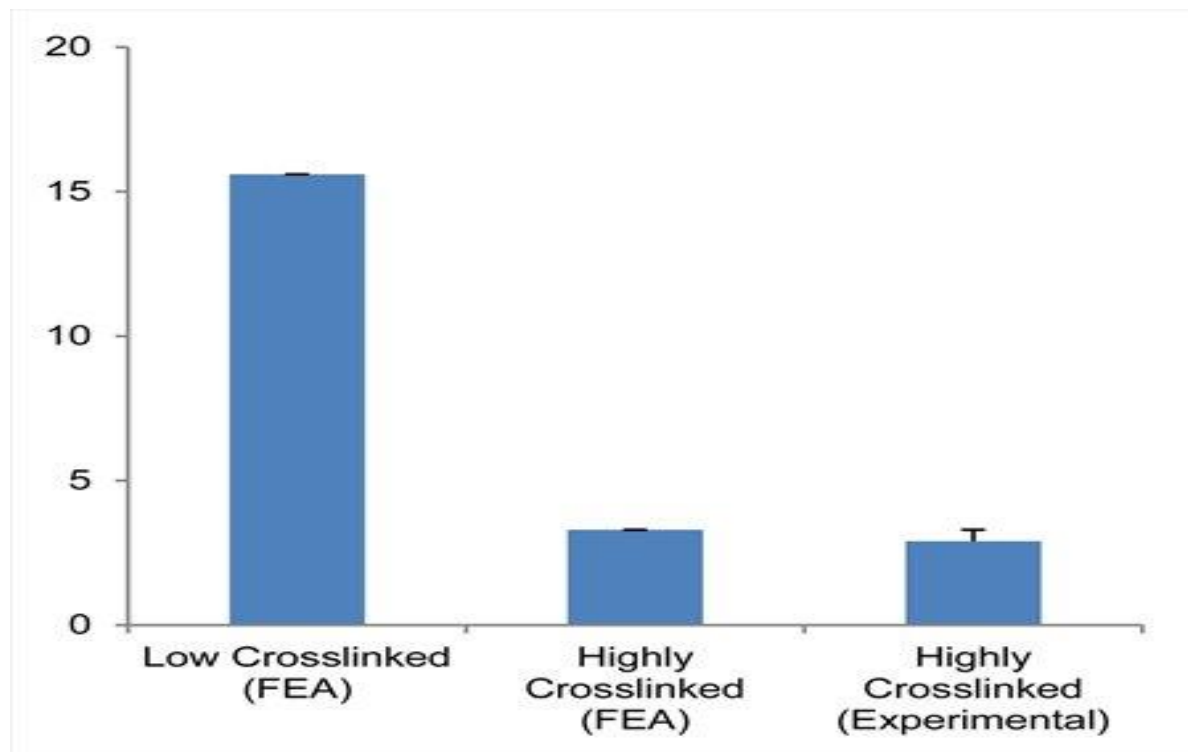
1. 在圆孔周围的磨损较小
2. 最大磨损量在螺孔的周围，而外围被内侧要大，是由于外围相对的位移量大造成的。
3. 在对称面附近磨损量相对较小



# 算例：全髋关节置换部件的磨损分析

Increased Wear in Low and High Crosslinked Polyethylene Due to Microseparation of Total Hip Arthroplasty Components

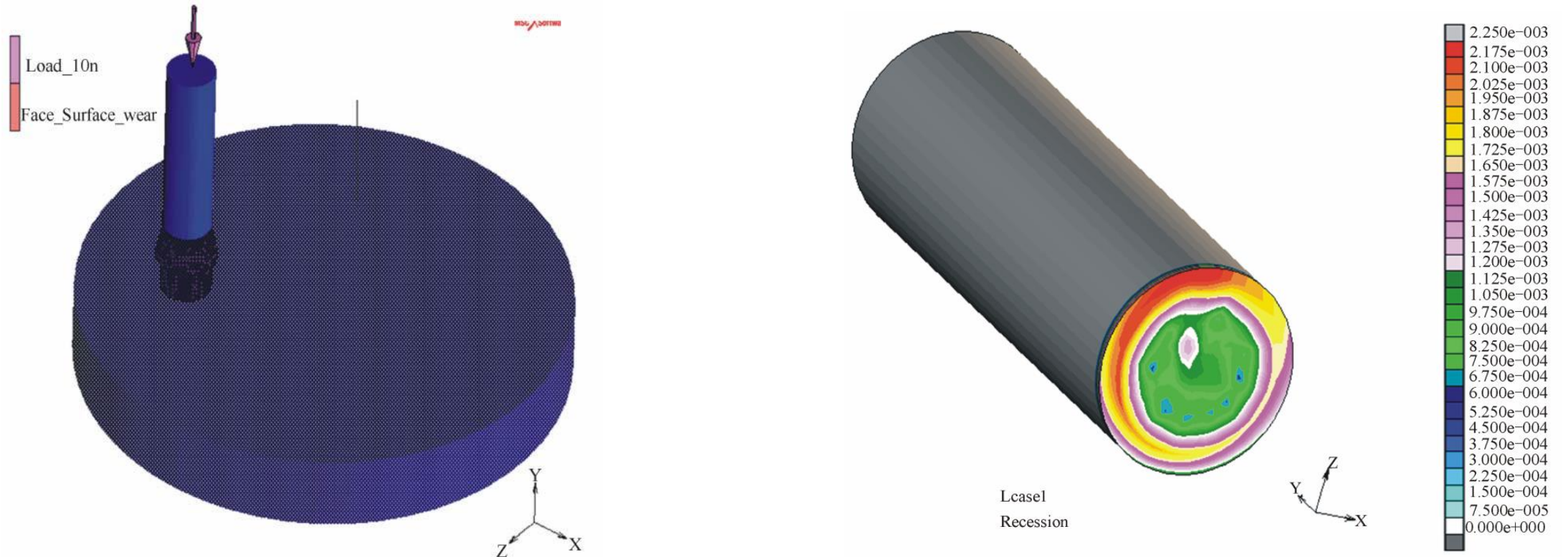
- ADM种植体修复体分析与对比
  - 实验组的微分离损失了 $2.9\text{mm}^3/\text{million}$ 循环
  - 有限元分析预测的体积损失为 $3.3\text{mm}^3/\text{million}$ 循环



# 算例：复合材料磨损分析

- Al/Al<sub>2</sub>SiO<sub>5</sub>/C冷激复合材料磨损行为的有限元模拟

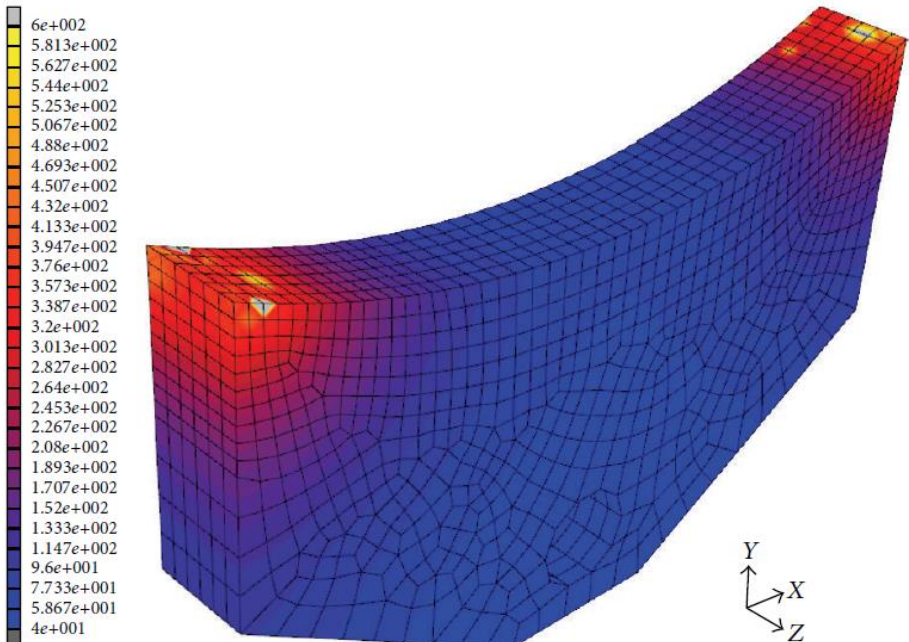
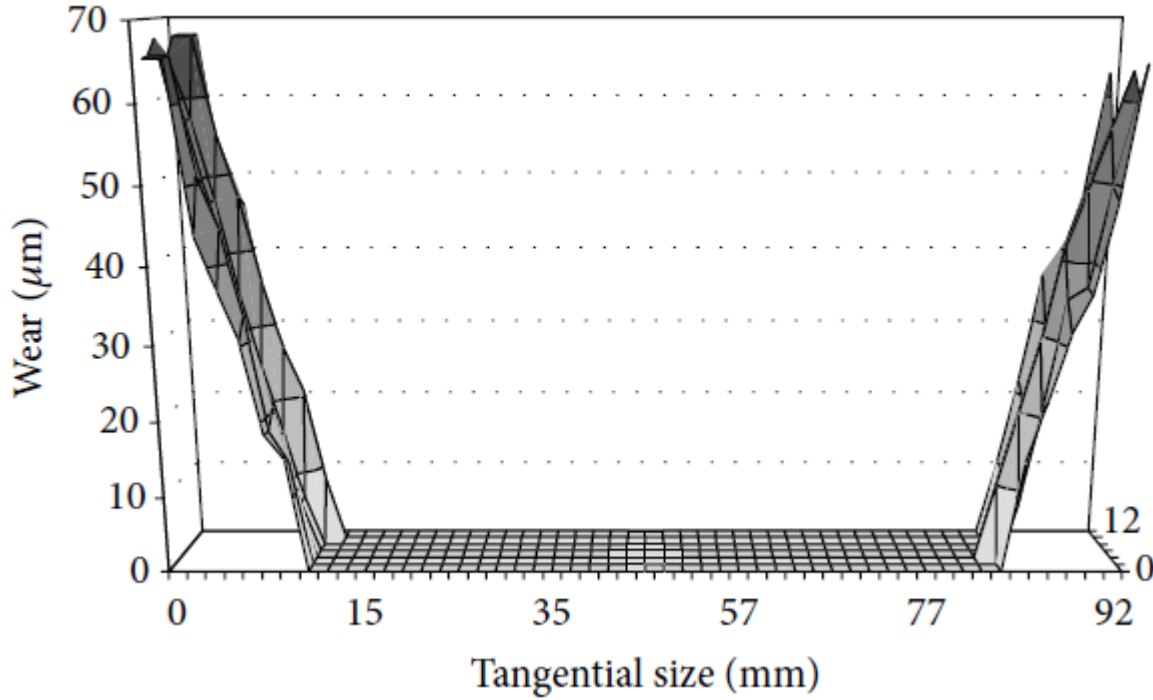
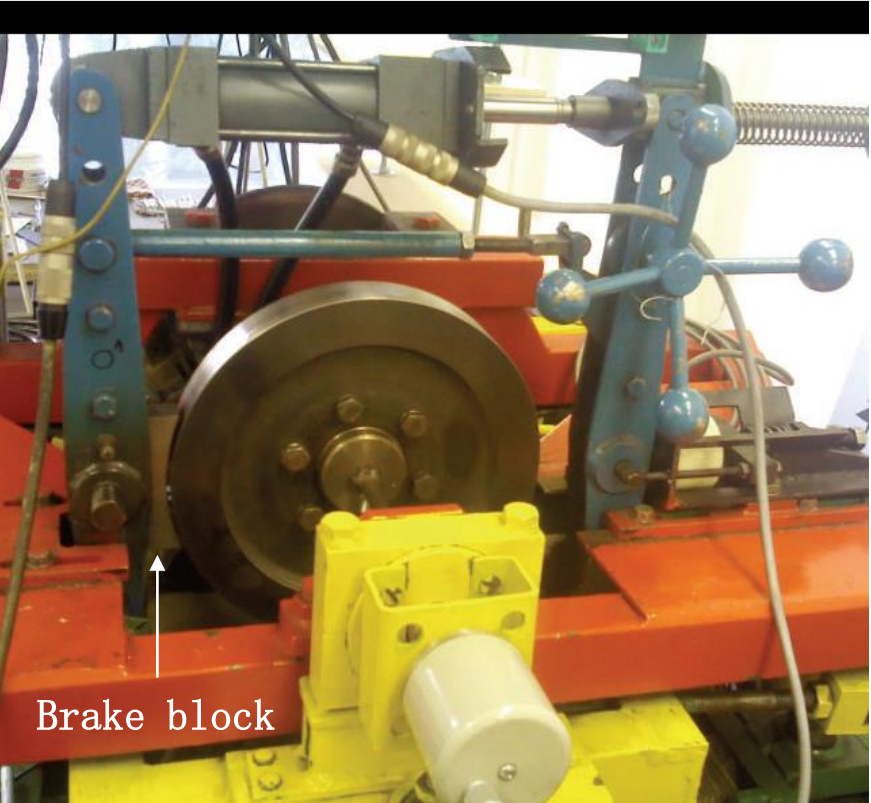
## (Finite Element Wear Behavior Modeling of Al/Al<sub>2</sub>SiO<sub>5</sub>/C Chilled Hybrid Metal Matrix Composites (CHMMCs) )





# 算例：刹车装置的磨损分析

- 热机耦合分析
- 接触摩擦生热分配不等

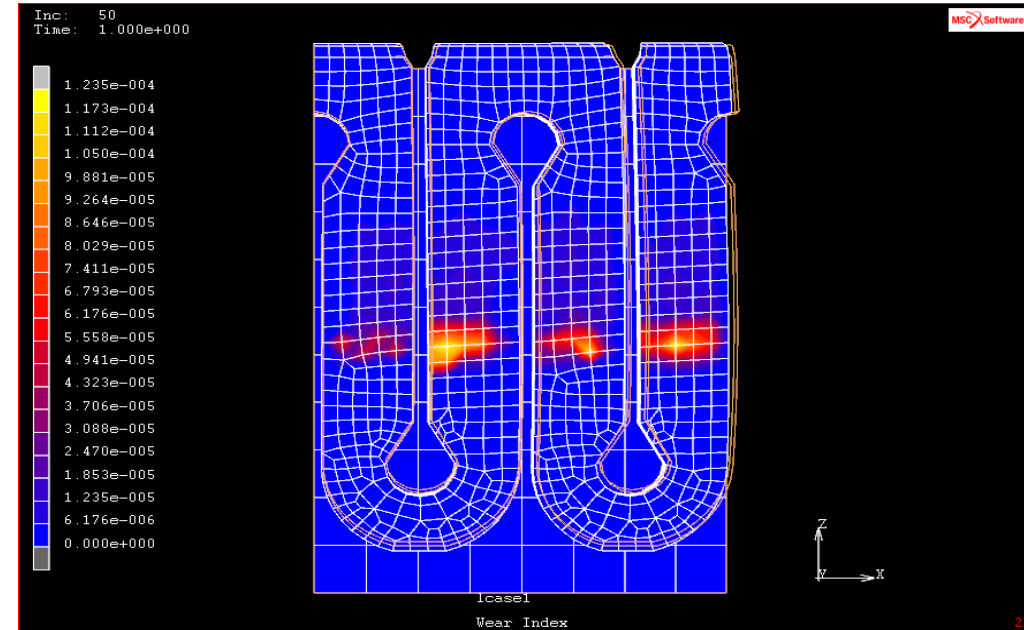
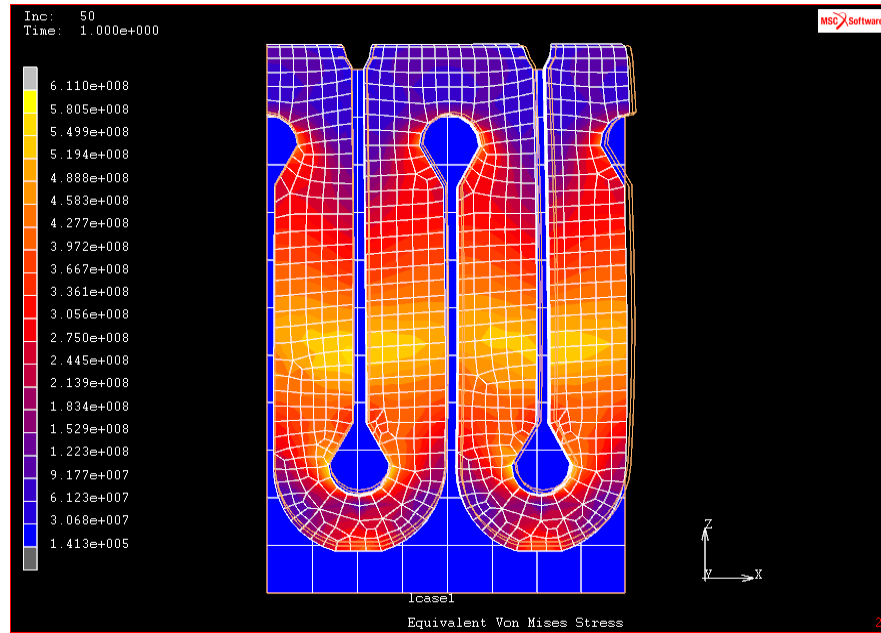
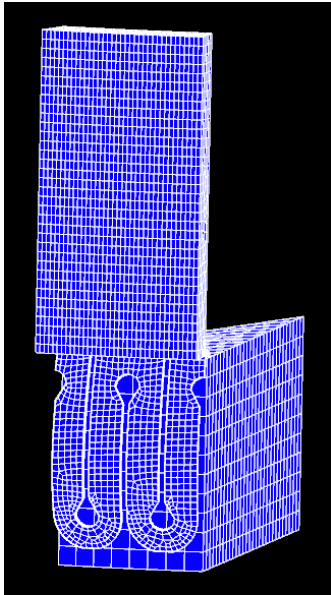


50秒后温度分布

# 算例：航天设备耐磨弹簧片磨损模拟

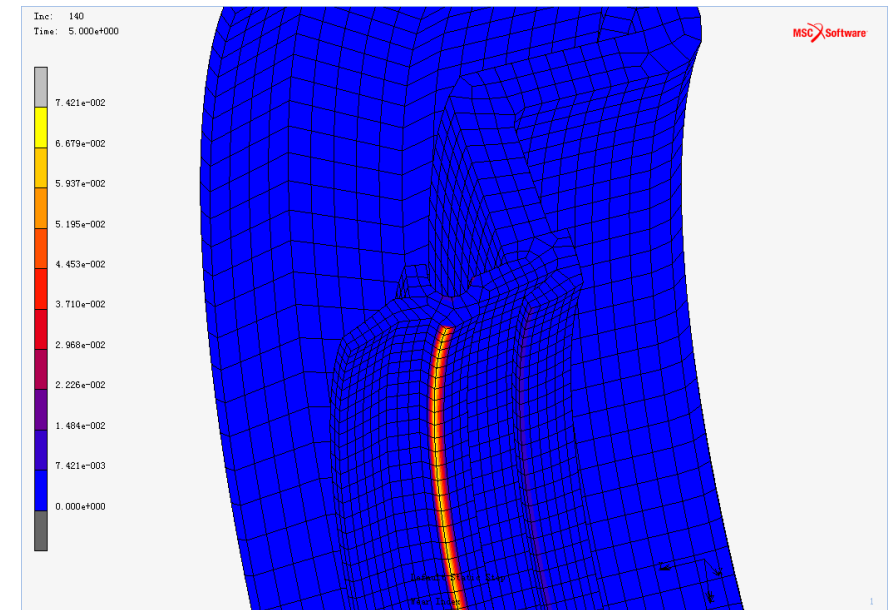
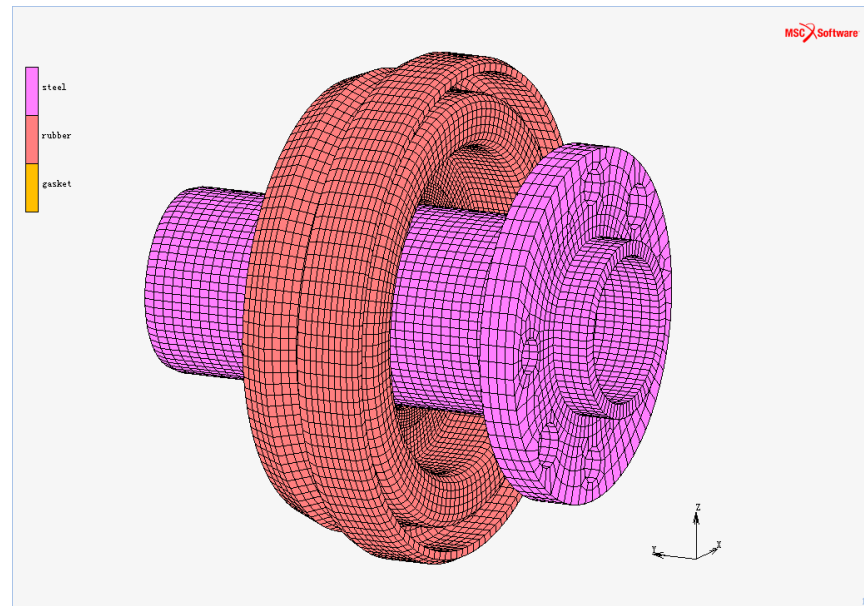
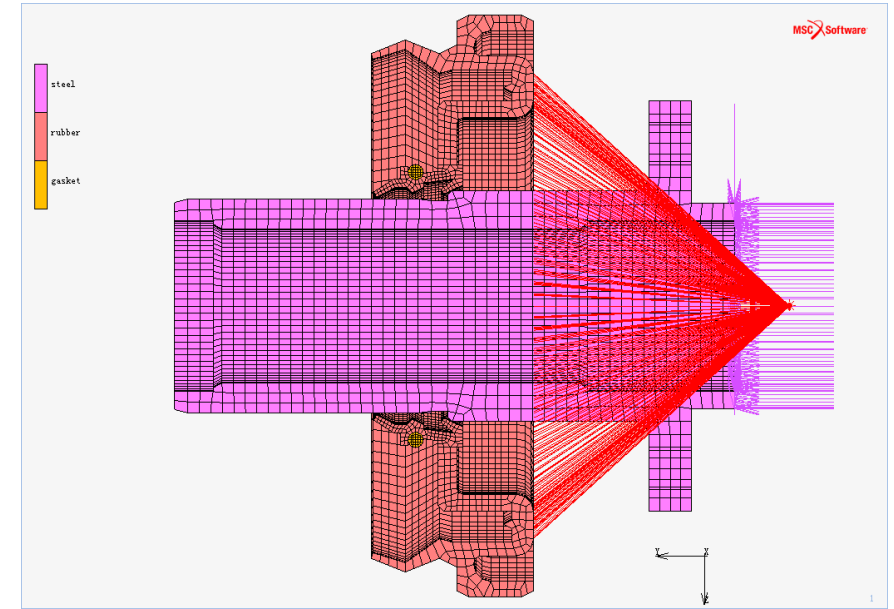
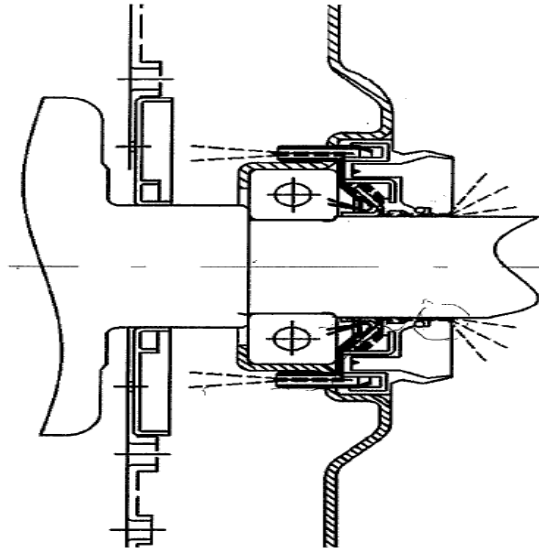
## ●航天设备耐磨弹簧片磨损模拟

- 两个圆柱型元件之间设计了一个弹簧片，考察一下该弹簧片的实际磨损情况。
- 因为是轴对称模型，分析中截取1/50几何模型，计算圆环形元件下移过程中弹簧片的磨损情况



# 算例：减速器防水结构进行了初步磨损分析

- 轴采用钢材材料模型，密封圈采用2项Mooney-Rivlin模型
- 采用Archard模型，选择更新几何选项



# 建议软件配置

模块名称	模块描述	个数	单价
Marc Complete Package (20175)	Marc 完整包, 包括求解器和 前后处理器常用功能	1	
Mentat CAE Solid Modeling (10612)	前处理器的几何建模和 Parasolid几何模型导入	1	
Mentat Generica Geometry Translators (10635)	前处理器通用几何模型接口	1	



# 谢谢!

