

Your True Partner for CAE&CFD
ICSC2014



GT-SUITE多体动力学仿真

IDAJ-China
张振科

本文来自: www.idaj.cn
谢绝未经IDAJ许可的转载!
技术咨询: support@idaj.cn



目录

- 曲轴设计分析
- 配气机构分析

本文来自：www.idaj.cn
谢绝未经IDAJ许可的转载！
技术咨询：support@idaj.cn



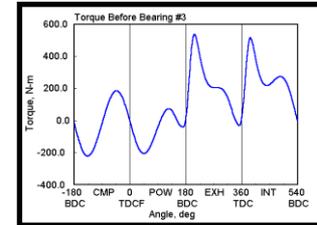
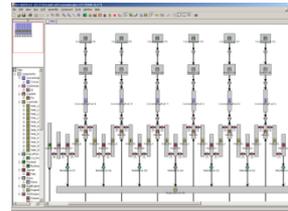
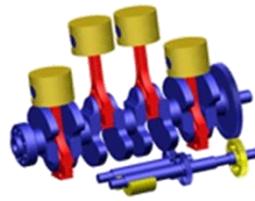
GT-SUITE

曲轴设计分析

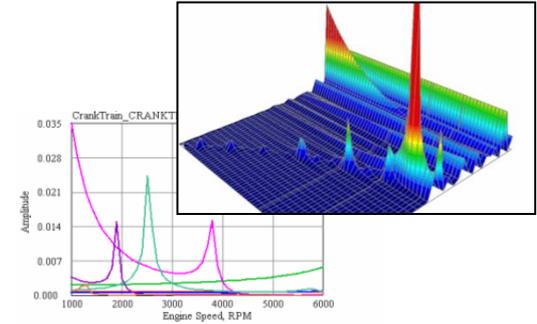
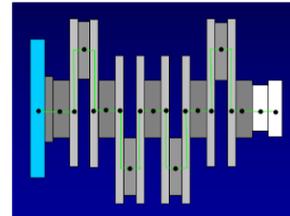
本文来自：www.idaj.cn
谢绝未经IDAJ许可的转载！
技术咨询：support@idaj.cn

曲轴动力学分析

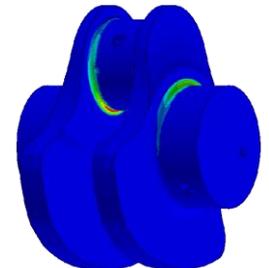
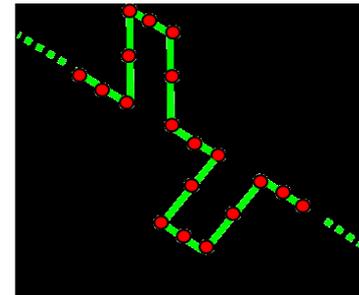
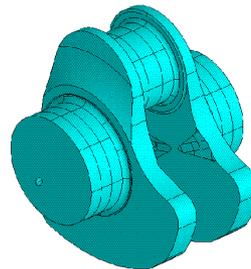
刚体，平衡分析



扭振分析
(时域或频域)

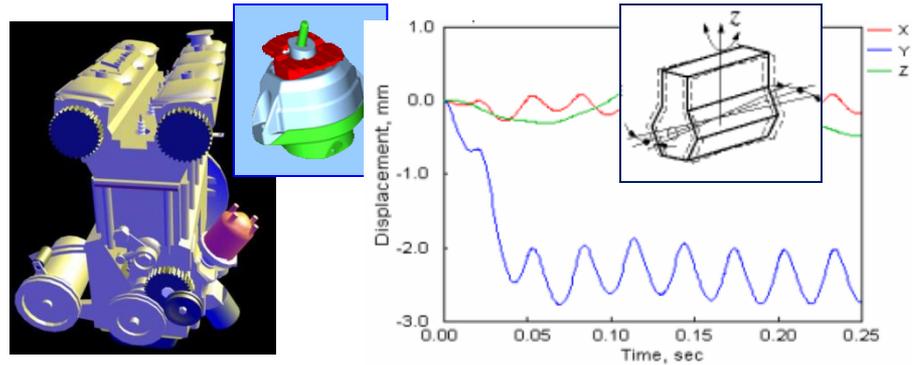


弯曲分析
(梁三维有限元模型)

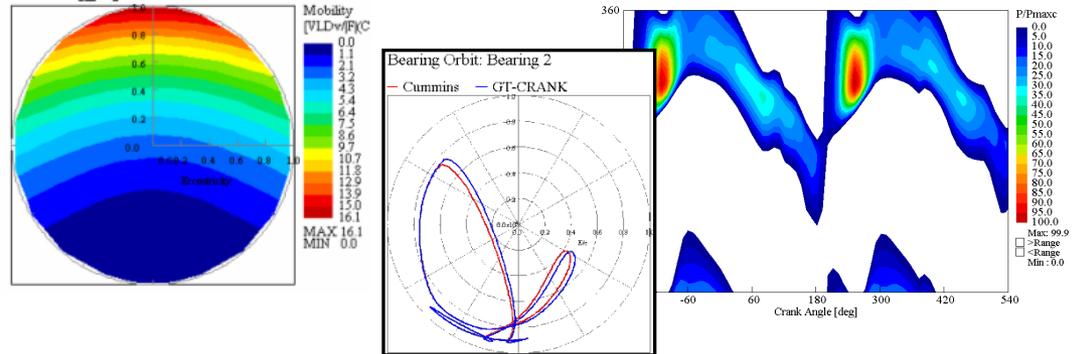


其它曲轴设计分析计算

缸体 + 机架
动力学

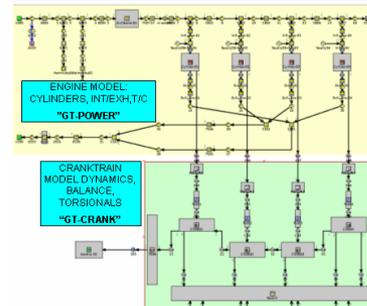


主轴 & 连杆
轴承

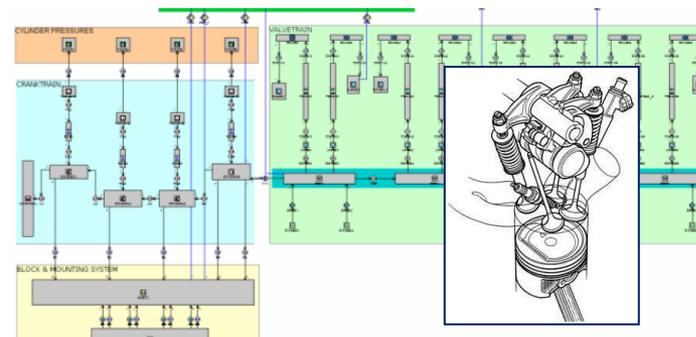


与其它发动机/车辆子系统集成

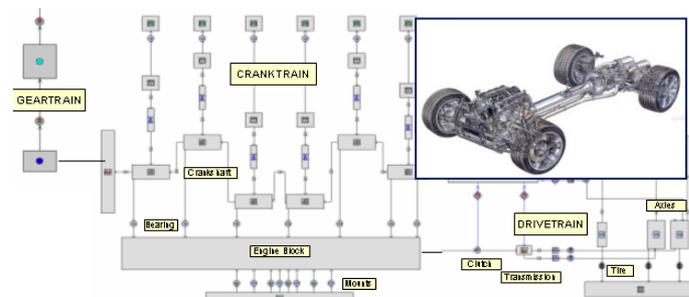
发动机，燃烧
(GT-POWER)



配气机构/凸轮轴

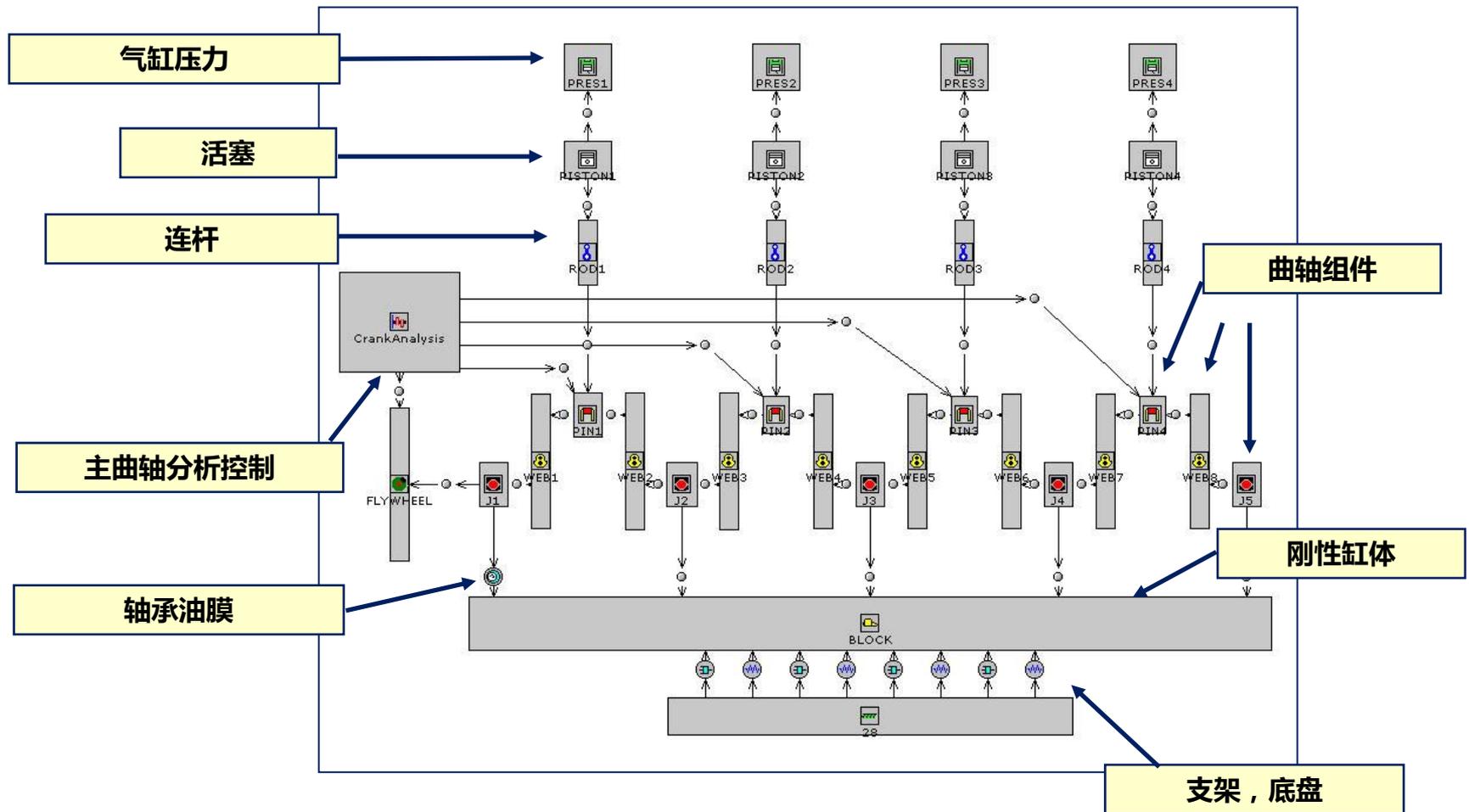


车辆传动系统



四缸发动机曲轴模型

本文来自: www.idaj.cn
谢绝未经IDAJ许可的转载!
技术咨询: support@idaj.cn

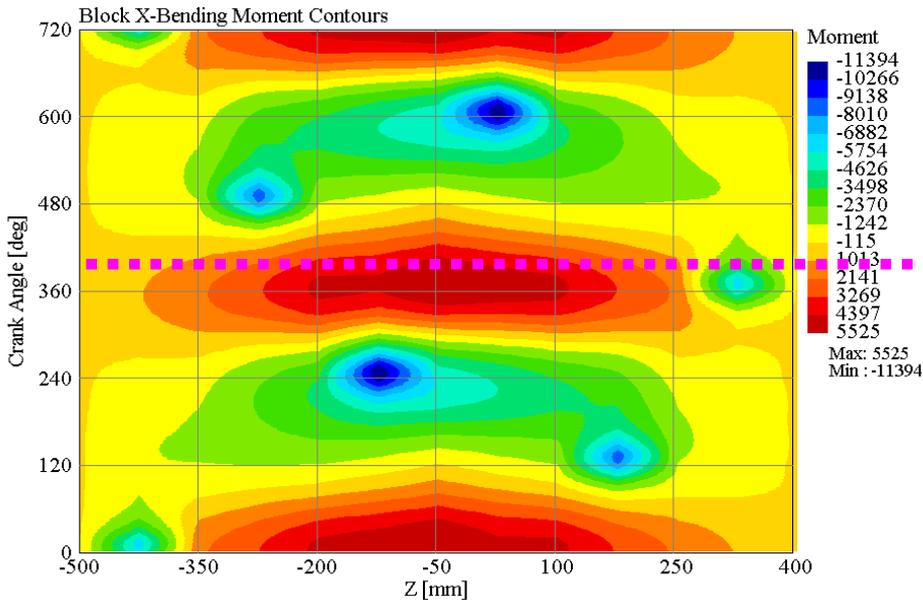


应用范围

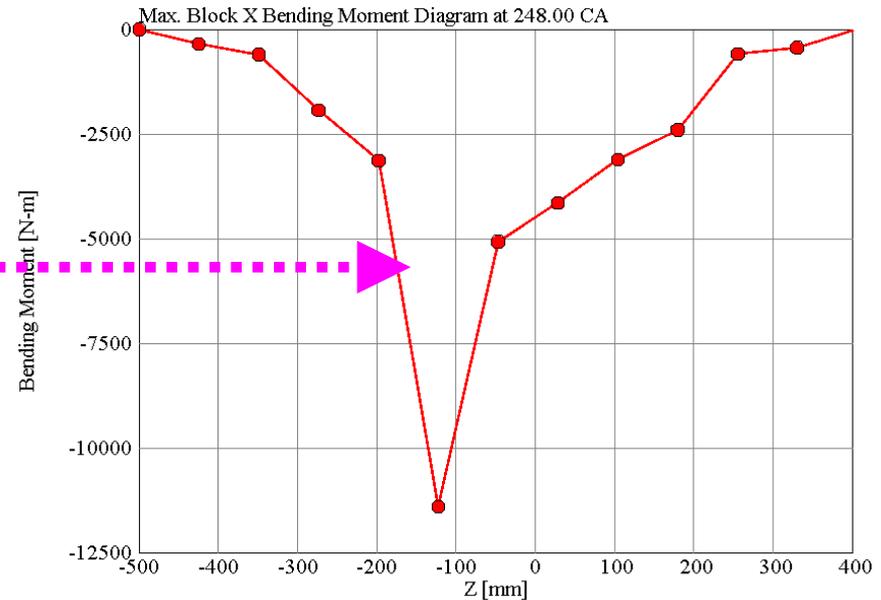
- 2或4冲程
- 任意气缸布局形式 (直列式, V型, W型, 对置式等)
- 单拐, 双拐或错拐
- V型发动机中左旋或右旋错拐
- 活塞销、曲柄和连杆的轴向偏移
- 各缸均可设置不同的属性 (压力、活塞、连杆、曲轴段数据)
- 完全任意的气缸编号方式
- 可输入不同转速的压力曲线 (之间采用插值法), 也可用平均有效压力生成的气缸压力曲线
- 稳态或瞬态分析
- 指定曲轴转速, 或指定载荷

缸体弯矩- M_x

缸体弯矩 vs 轴向位置 & 曲柄角



缸体弯矩 vs 轴向位置(取最大缸体弯矩)



- 输出缸体上瞬时和总的最大“弯曲”力矩 M_x , M_y
- 缸体载荷的一个度量
- 可用于建立某种设计标准



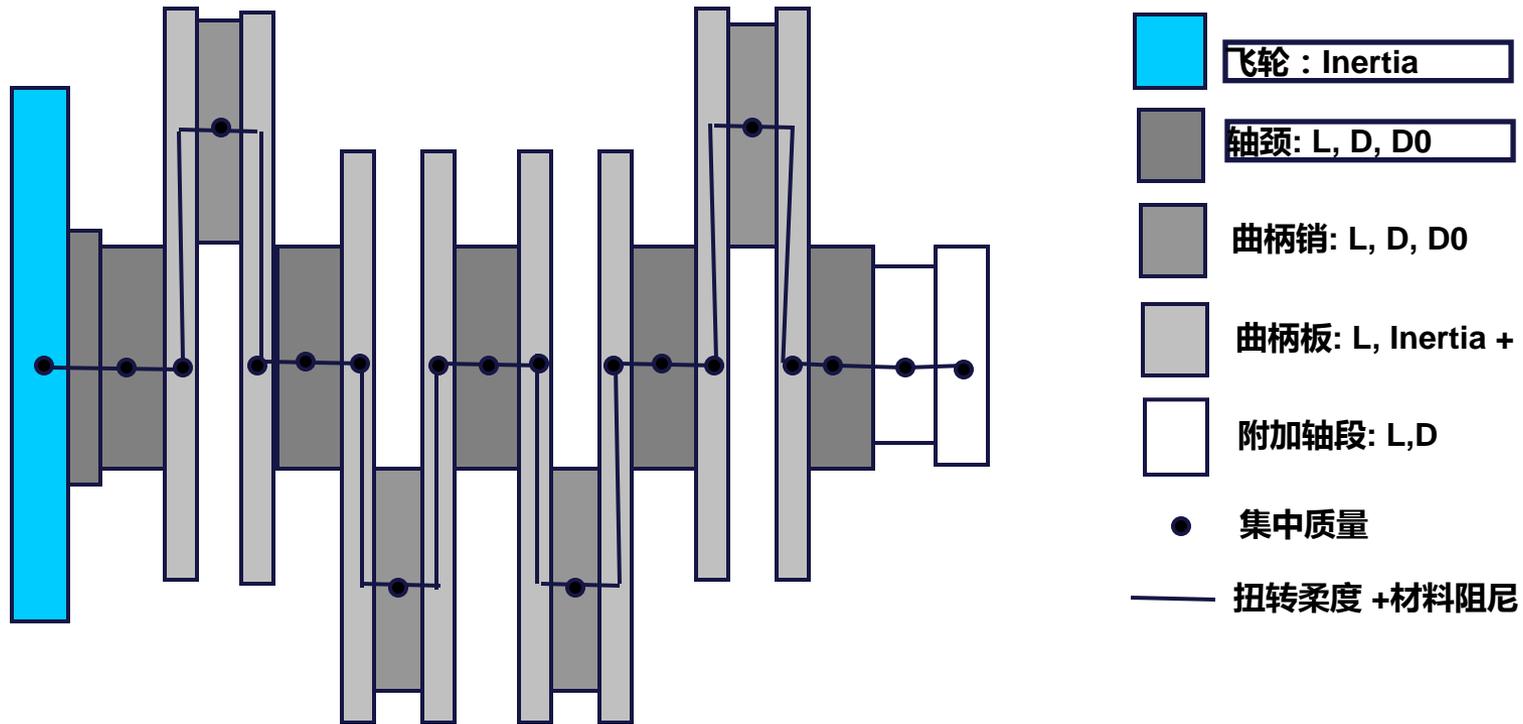
输出所有缸体受力

- 以列格式输出所有轴承和气缸传递给缸体的瞬时力，包括活塞侧载荷作用的轴向位置（曲柄角每次增量为1°）

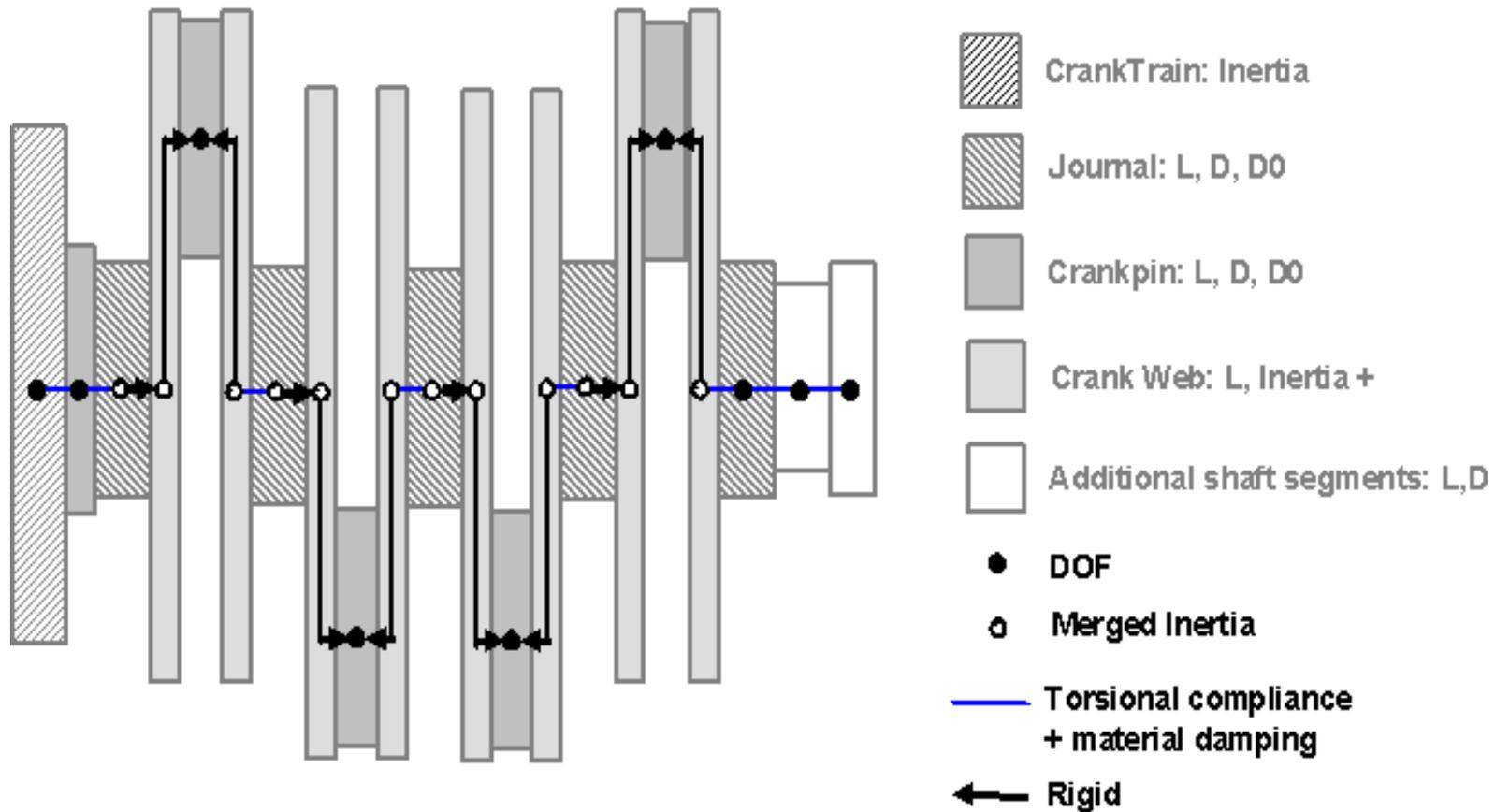
#	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X	Y
1	721	i4.gdt																							
2	X-LABEL	FXM05:BL	FYM05:BL	FZM05:BL	MXM05:BL	MYM05:BL	MZM05:BL	FXM06:BL	FYM06:BL	FZM06:BL	MXM06:BL	MYM06:BL	MZM06:BL	FXM07:BL	FYM07:BL	FZM07:BL	MXM07:BL	MYM07:BL	MZM07:BL	FXM08:BL	FYM08:BL	FZM08:BL	MXM08:BL	MYM08:BL	MZM08:BL
3	X-COMME	Block force	Block force	Block force	Moment at	Moment at	Moment at	Block force	Block force	Block force	Moment at	Moment at	Moment at	Block force	Block force	Block force	Moment at	Moment at	Moment at	Block force	Block force	Block force	Moment at	Moment at	Moment at
4	X-UNIT	N	N	N	N-m	N-m	N-m	N	N	N	N-m	N-m	N-m	N	N	N	N-m	N-m	N-m	N	N	N	N-m	N-m	N-m
5		-109	-321.41	-2.21E-30	-1.04E-43	0	-38.5692	41.2541	-72.9307	-5.02E-31	-2.38E-44	0	-2.91723	11.2604	-72.9307	-5.02E-31	-2.38E-44	0	2.91723	11.2604	-321.41	-2.21E-30	-1.04E-43	0	38.5692
6		-108	-316.822	-2.18E-30	-1.02E-43	0	-38.0186	40.8576	-59.7997	-4.11E-31	-1.96E-44	0	-2.39199	9.19014	-59.7997	-4.11E-31	-1.96E-44	0	2.39199	9.19014	-316.822	-2.18E-30	-1.02E-43	0	38.0186
7		-107	-311.836	-2.15E-30	-9.95E-44	0	-37.4203	40.4058	-46.5888	-3.21E-31	-1.54E-44	0	-1.86355	7.12639	-46.5888	-3.21E-31	-1.54E-44	0	1.86355	7.12639	-311.836	-2.15E-30	-9.95E-44	0	37.4203
8		-106	-306.453	-2.11E-30	-9.81E-44	0	-36.7743	39.8981	-33.3203	-2.29E-31	-1.12E-44	0	-1.33281	5.07282	-33.3203	-2.29E-31	-1.12E-44	0	1.33281	5.07282	-306.453	-2.11E-30	-9.81E-44	0	36.7743
9		-105	-300.672	-2.07E-30	-9.67E-44	0	-36.0807	39.3336	-20.0166	-1.38E-31	-7.01E-45	0	-0.80067	3.033	-20.0166	-1.38E-31	-7.01E-45	0	0.800665	3.033	-300.672	-2.07E-30	-9.67E-44	0	36.0807
10		-104	-294.497	-2.03E-30	-9.39E-44	0	-35.3396	38.7116	-6.70005	-4.61E-32	-2.80E-45	0	-0.268	1.01039	-6.70005	-4.61E-32	-2.80E-45	0	0.268002	1.01039	-294.497	-2.03E-30	-9.39E-44	0	35.3396
11		-103	-287.928	-1.98E-30	-9.25E-44	0	-34.5514	38.0317	6.60737	4.54E-32	2.80E-45	0	0.264295	-0.99166	6.60737	4.54E-32	2.80E-45	0	-0.2643	-0.99166	-287.928	-1.98E-30	-9.25E-44	0	34.5514
12		-102	-280.97	-1.93E-30	-8.97E-44	0	-33.7164	37.2932	19.8838	1.37E-31	7.01E-45	0	0.795353	-2.96991	19.8838	1.37E-31	7.01E-45	0	-0.79535	-2.96991	-280.97	-1.93E-30	-8.97E-44	0	33.7164
13		-101	-273.626	-1.88E-30	-8.83E-44	0	-32.8352	36.4958	33.1078	2.28E-31	1.12E-44	0	1.32431	-4.92124	33.1078	2.28E-31	1.12E-44	0	-1.32431	-4.92124	-273.626	-1.88E-30	-8.83E-44	0	32.8352
14		-100	-265.902	-1.83E-30	-8.55E-44	0	-31.9082	35.6393	46.258	3.18E-31	1.54E-44	0	1.85032	-6.84266	46.258	3.18E-31	1.54E-44	0	-1.85032	-6.84266	-265.902	-1.83E-30	-8.55E-44	0	31.9082
15		-99	-257.802	-1.77E-30	-8.27E-44	0	-30.9363	34.7235	59.3138	4.08E-31	1.96E-44	0	2.37255	-8.73131	59.3138	4.08E-31	1.96E-44	0	-2.37255	-8.73131	-257.802	-1.77E-30	-8.27E-44	0	30.9363
16		-98	-249.334	-1.71E-30	-7.99E-44	0	-29.9201	33.7484	72.2547	4.97E-31	2.38E-44	0	2.89019	-10.5844	72.2547	4.97E-31	2.38E-44	0	-2.89019	-10.5844	-249.334	-1.71E-30	-7.99E-44	0	29.9201
17		-97	-240.504	-1.65E-30	-7.71E-44	0	-28.8605	32.714	85.0609	5.85E-31	2.66E-44	0	3.40244	-12.3995	85.0609	5.85E-31	2.66E-44	0	-3.40244	-12.3995	-240.504	-1.65E-30	-7.71E-44	0	28.8605

本文来自：www.idaj.cn
 谢绝未经IDAJ许可的转载！
 技术咨询：support@idaj.cn

曲柄扭振模型



扭振模型中缩减自由度





曲轴扭振—频域分析

快速线性分析模式 (只需要秒级CPU时间)

多系统 (比如带传动系统的发动机)

非线性, 频率相关的刚度和阻尼

自由振动分析

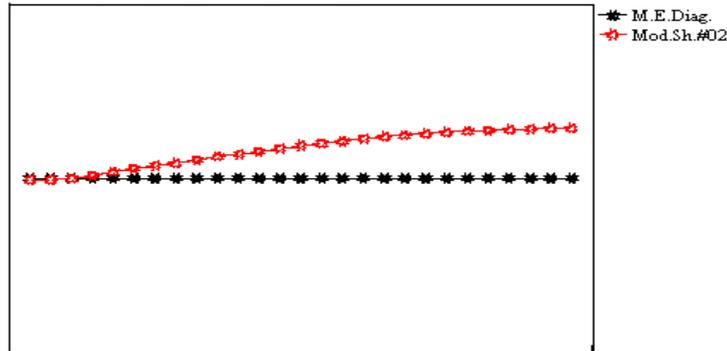
- 扭转模态频率 (表)
- 模态形状 (图)

受迫振动分析

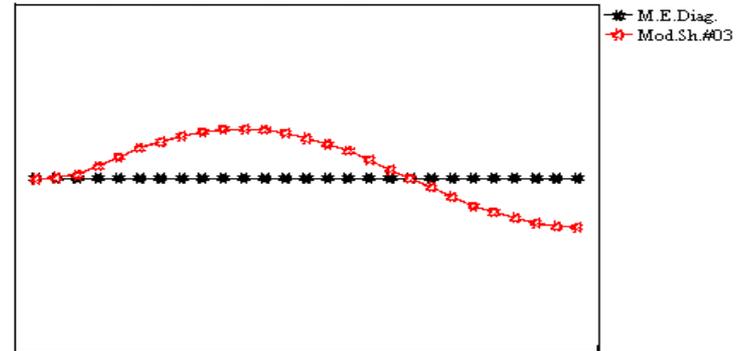
- 发动机转速自动扫描, 可变气缸压力 (独立的或插值), 可以添加速度相关的外部扭矩
- 在受迫振动分析的转速扫描中自动检测/包含共振转速

自由扭振频域分析- 前4阶弹性模态

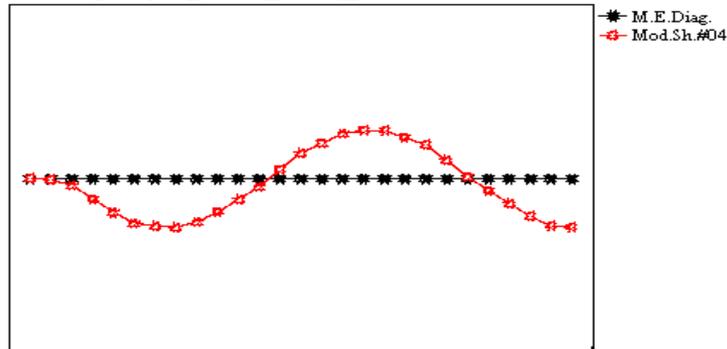
Mode Shape 02 - Frequency = 416.61 Hz
TorsFreqAnalysis_TORS_FREQ_ANALYSIS



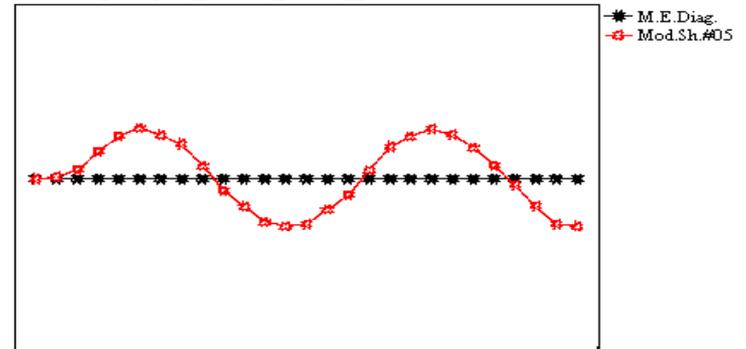
Mode Shape 03 - Frequency = 1218.50 Hz
TorsFreqAnalysis_TORS_FREQ_ANALYSIS



Mode Shape 04 - Frequency = 2016.66 Hz
TorsFreqAnalysis_TORS_FREQ_ANALYSIS

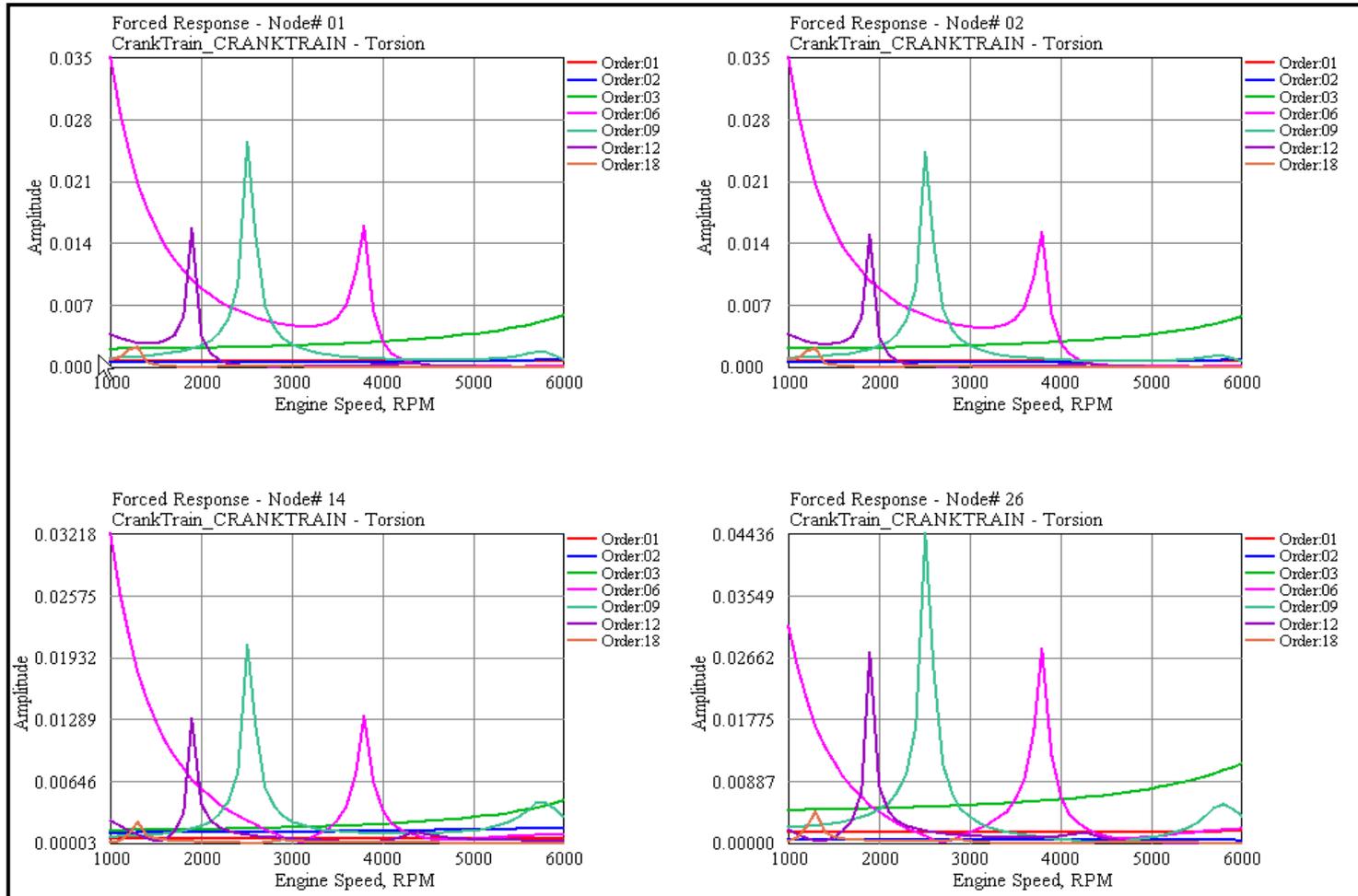


Mode Shape 05 - Frequency = 2799.84 Hz
TorsFreqAnalysis_TORS_FREQ_ANALYSIS



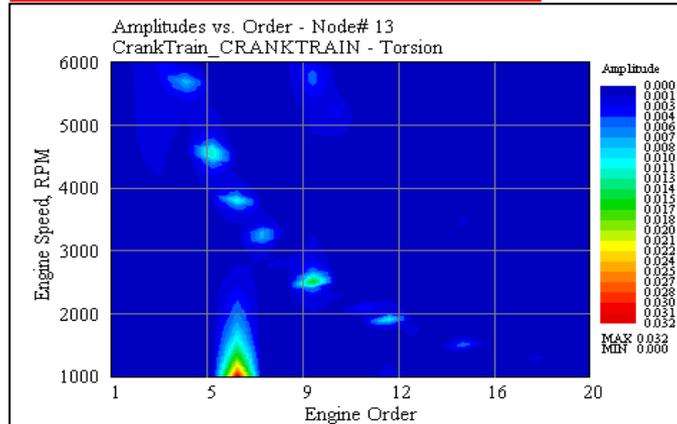


受迫扭振频域分析- 谐波响应 vs. 转速

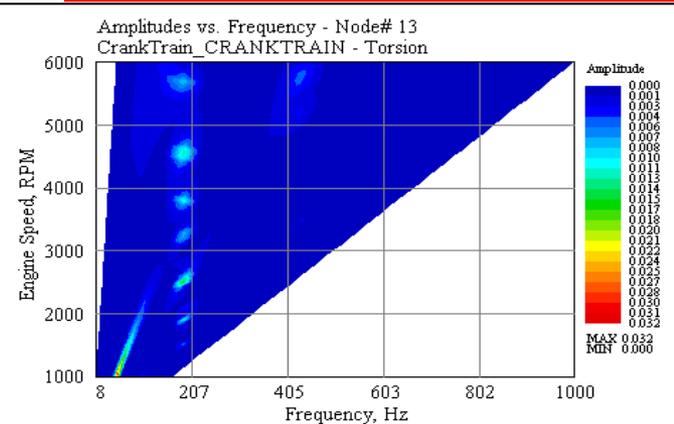


受迫扭振频域分析 - 响应 vs. 阶次/频率 & 转速

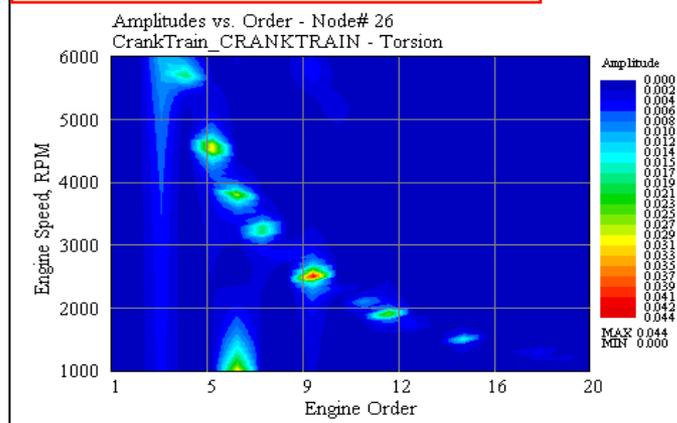
VS ORDER - AFTER MIDDLE CYLINDER



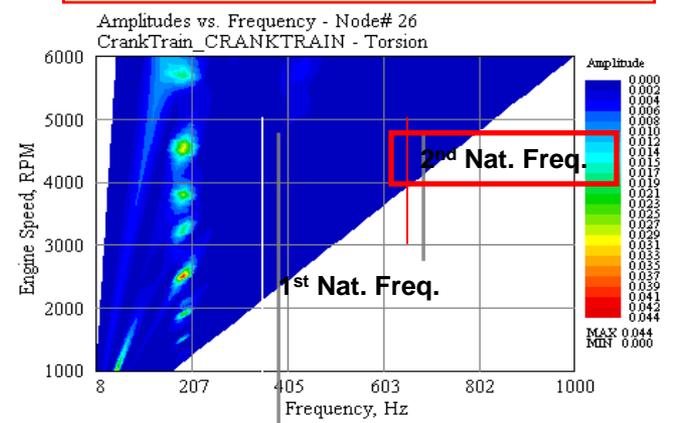
VS FREQUENCY - AFTER MIDDLE CYLINDER



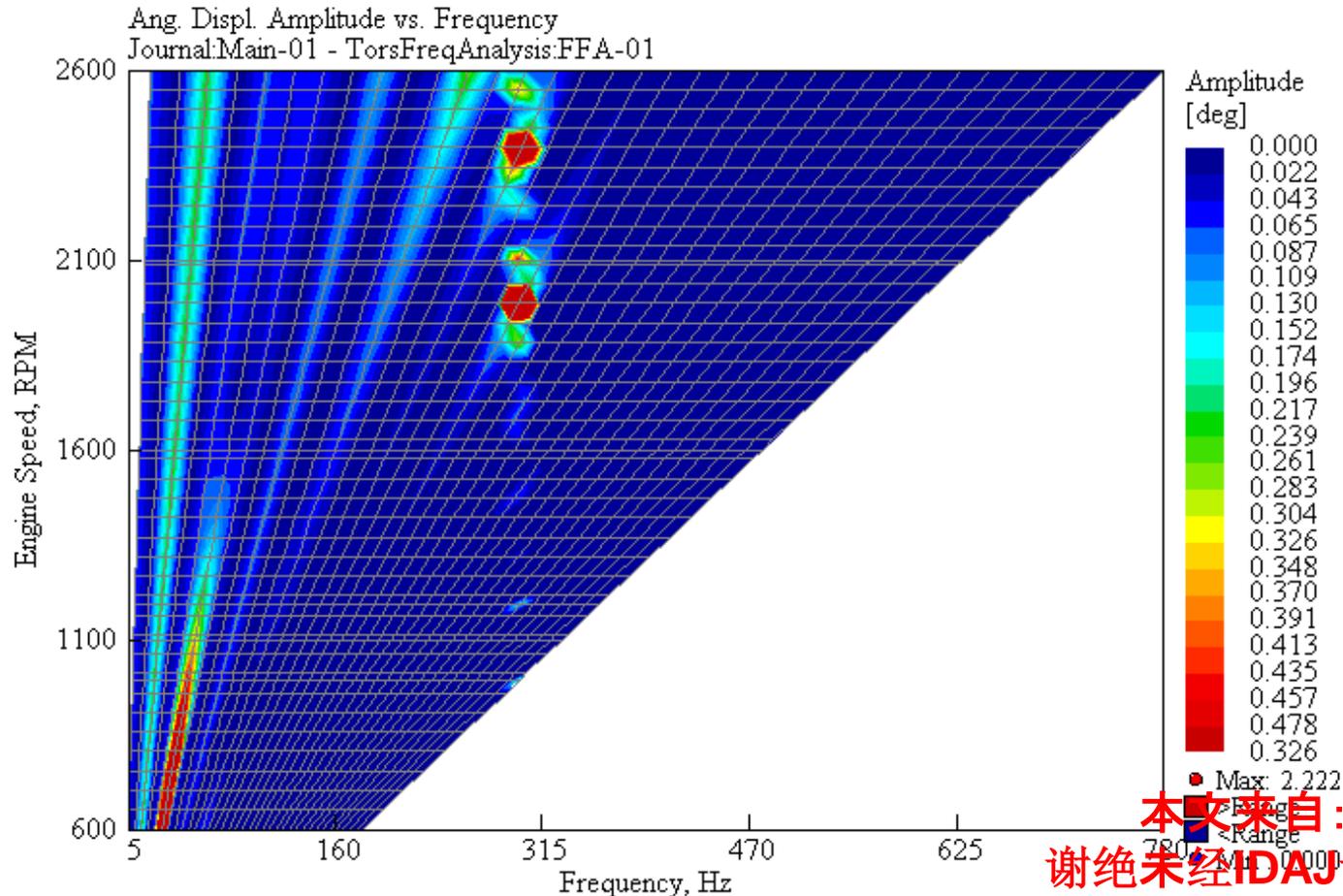
VS ORDER - AFTER LAST CYLINDER



VS FREQUENCY - AFTER LAST CYLINDER

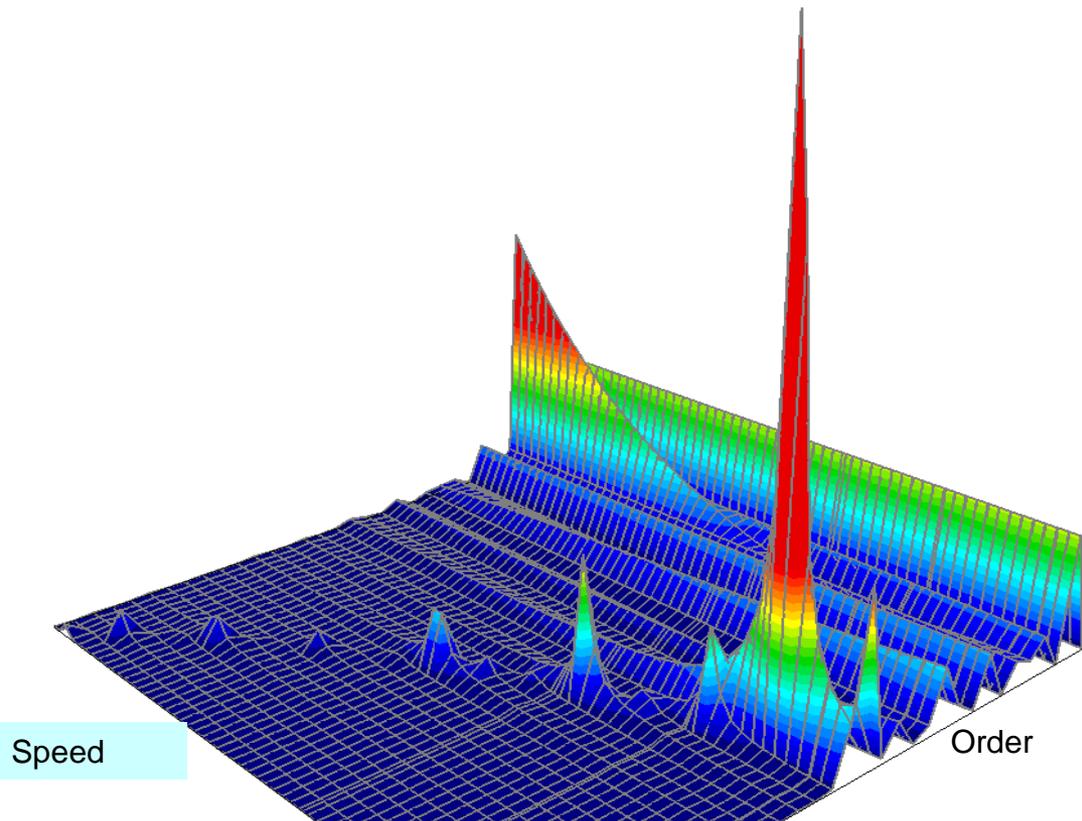


共振频率自动检测



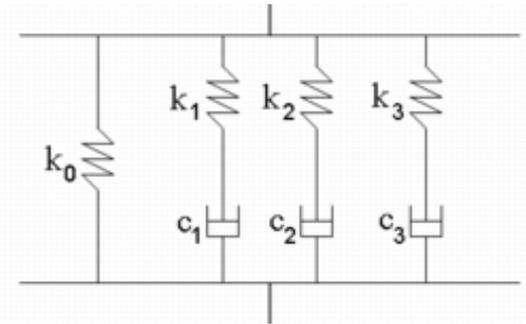
本文来自: www.idaj.cn
谢绝未经IDAJ许可的转载!
技术咨询: support@idaj.cn

转速扫描 : 2维/3维 响应图 vs. 阶次或频率



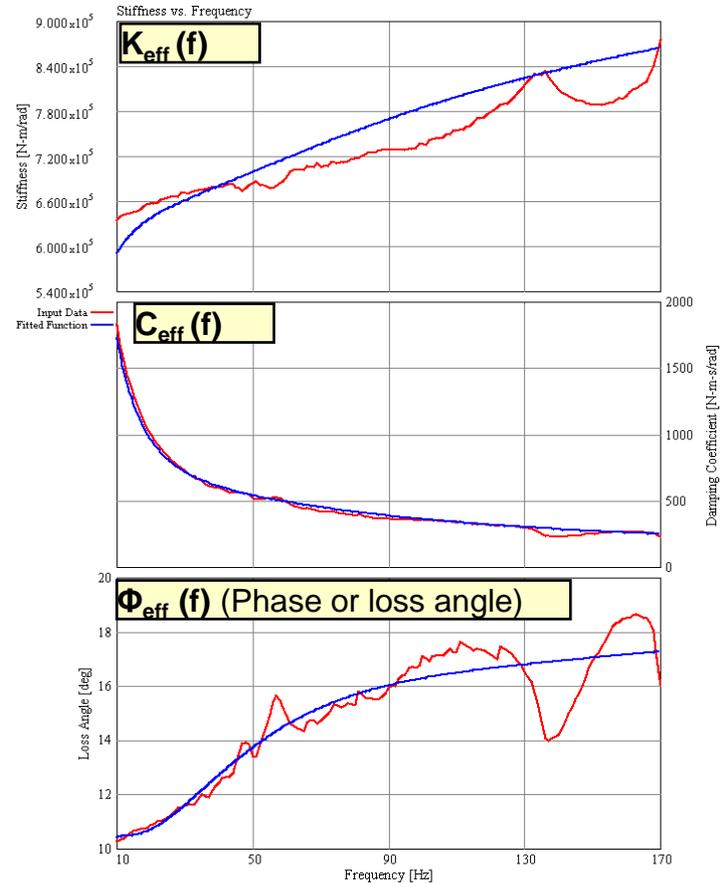
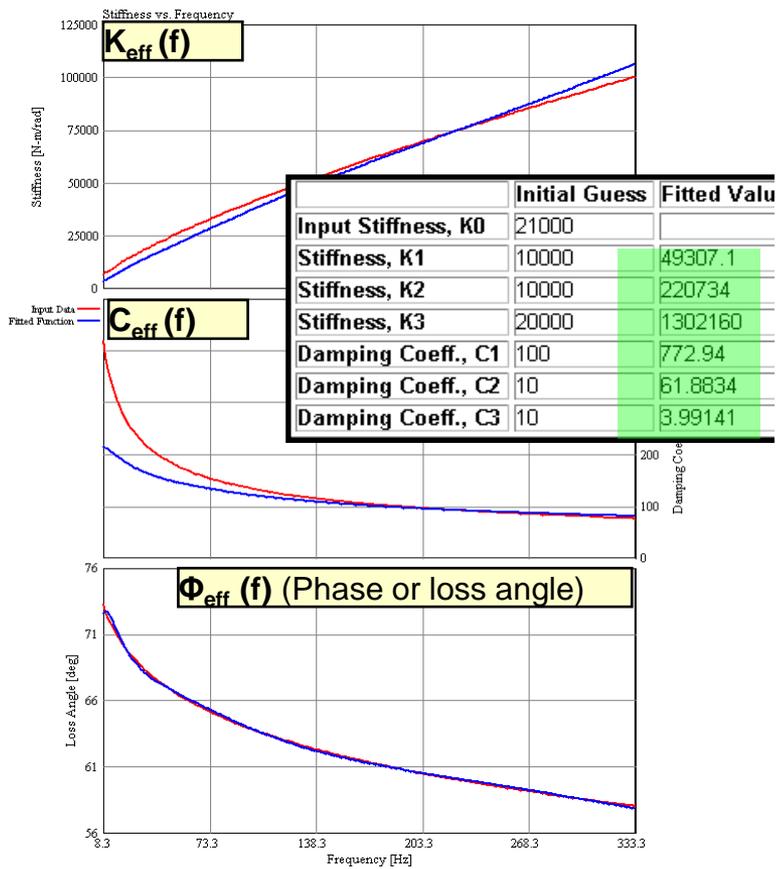
橡胶减震器建模

- 将橡胶减震器作为一个Maxwell-Reichert固体建模



- 模型在频率相关的有效刚度/阻尼和频率之间建立关系 ($K_{\text{eff}}(f)$, $C_{\text{eff}}(f)$, 通常由实验测量得到) 并通过自动最小二乘法拟合得到Maxwell模型刚度和阻尼参数 ($k_0, k_1, k_2, k_3, c_1, c_2, c_3$)
- 对于时域和频域分析可以给出物理上一致的描述

实验数据拟合 : K_{eff}, C_{eff}



Data Set 1

Data Set 2

轴承油膜模型

流体动力学解：阻抗法和导纳法

- 阻抗法和导纳法互为镜像
- 导纳法用于主轴承或连杆轴承做刚体、扭振或准静态弯曲的曲轴动力学求解 (例如轴承反力未知时)
- 阻抗法用于主轴承的全动态求解(轴颈状态已知，解提供反力)

详细油膜输出

- 轨道最小油膜厚度
- 最大压力及位置
- 流量 (流体动力学, Martin, Martin-Xu等模型)
- 油膜范围 ($P=0$, $P=0.5P_{max}$, $P=P_{max}$)

热平衡及油流动计算

油孔和槽和简化计算

加压孔和槽的静压效果 (对于载荷)

可以和曲轴弯曲耦合求解 (准静态或动态)

1) 曲轴颈和 2) 缸体上轴承之间的失调



曲轴三维弹性（弯曲）模型

梁三维有限元计算

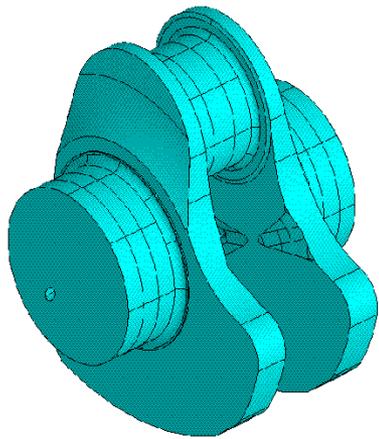
有两种计算模式:

- 准静态
- 动态

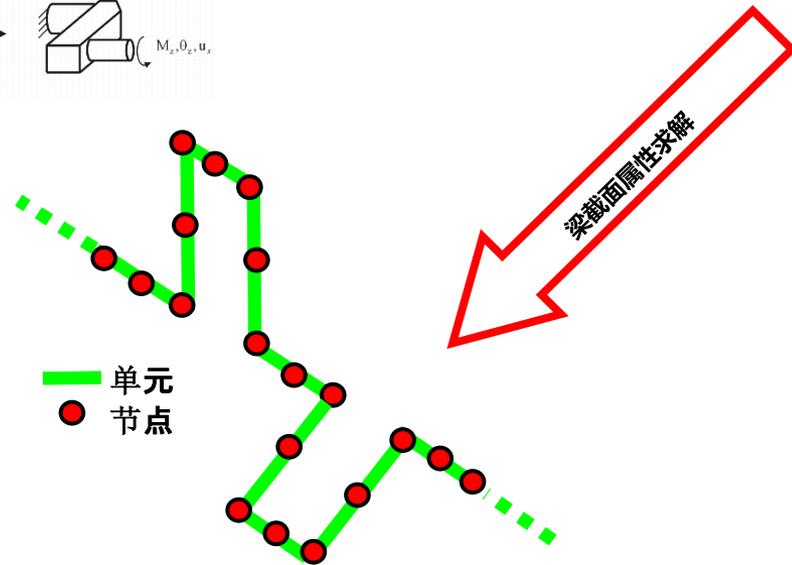
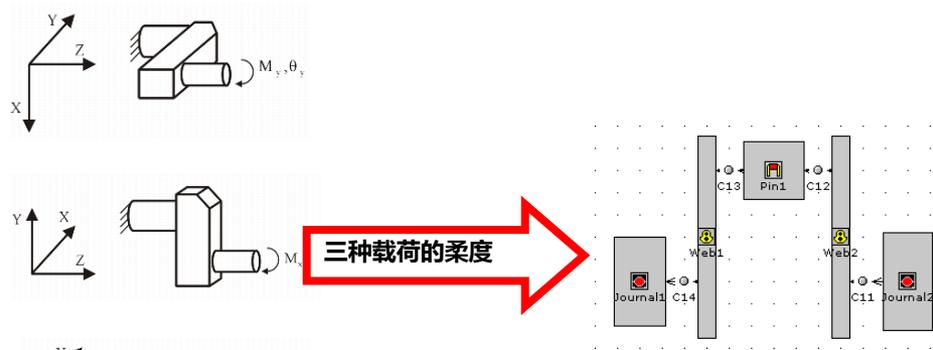
在动态模式中，线弹性位移叠加于三维刚体运动之上

在准静态模式中，线弹性位移基于平衡构型得到

等效梁三维有限元模型

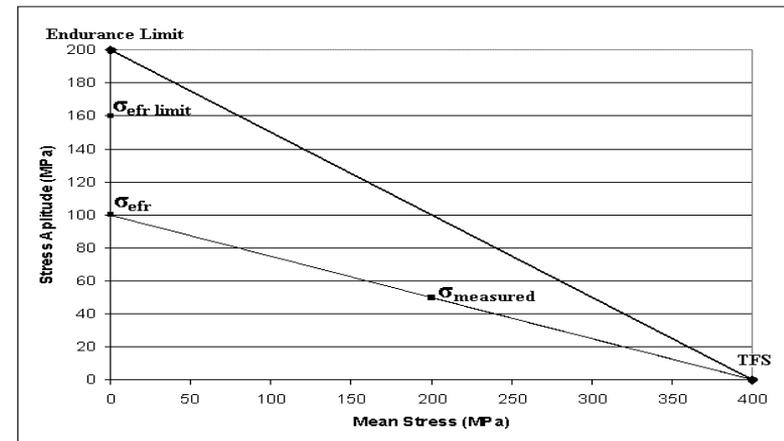
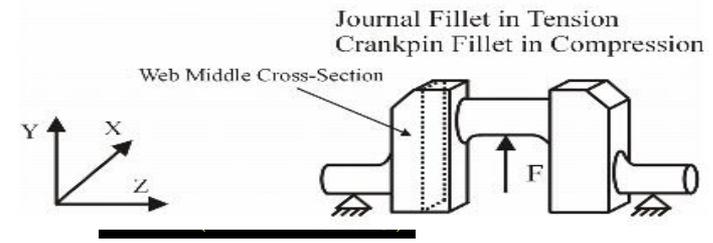
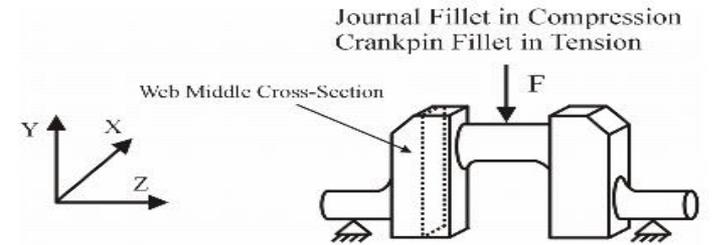


三维曲轴实体有限元模型
给出柔度用于自动创建等
效梁三维有限元模型

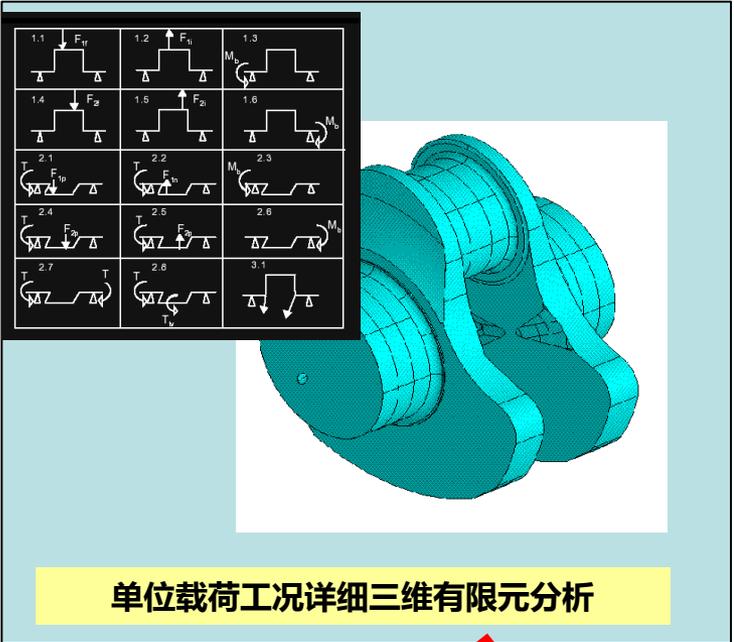


曲轴应力 & 后处理选项

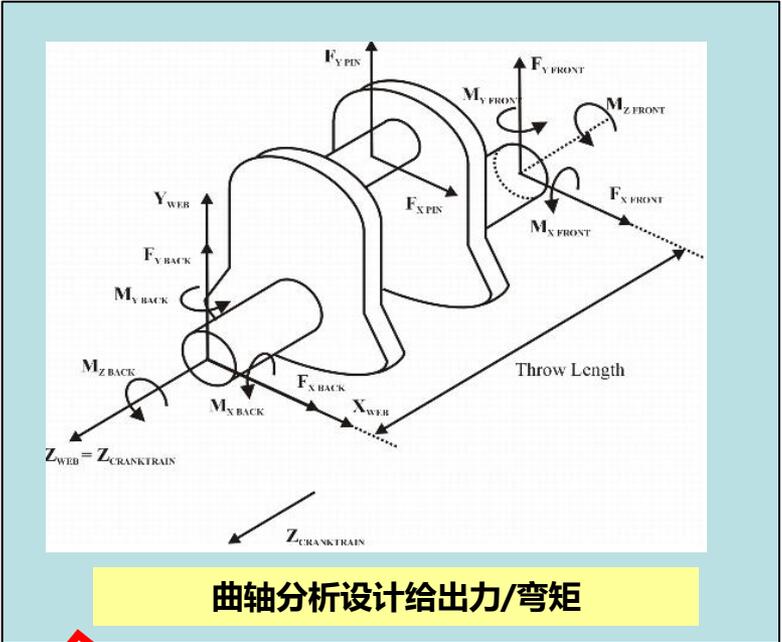
1. 三维梁单元基础输出 包括剪力、力矩、扭矩以及应力 (vs. 时间, 平均值, 最小值, 最大值, 范围)
2. 主轴和曲轴销圆角集中应力
 - 基于用户定义的应力/弯矩比 (可以通过此前的三维有限元分析给出)
 - 可选的疲劳周期计算
3. 主轴和曲轴销圆角集中应力 (IACS M53)
 - 船用柴油机的曲轴认证标准
 - 基于弯扭联合载荷



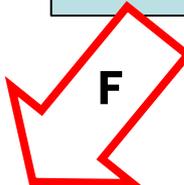
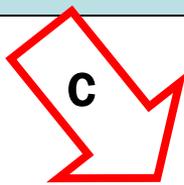
EFR应力/疲劳法



单位载荷工况详细三维有限元分析



曲轴分析设计给出力/弯矩



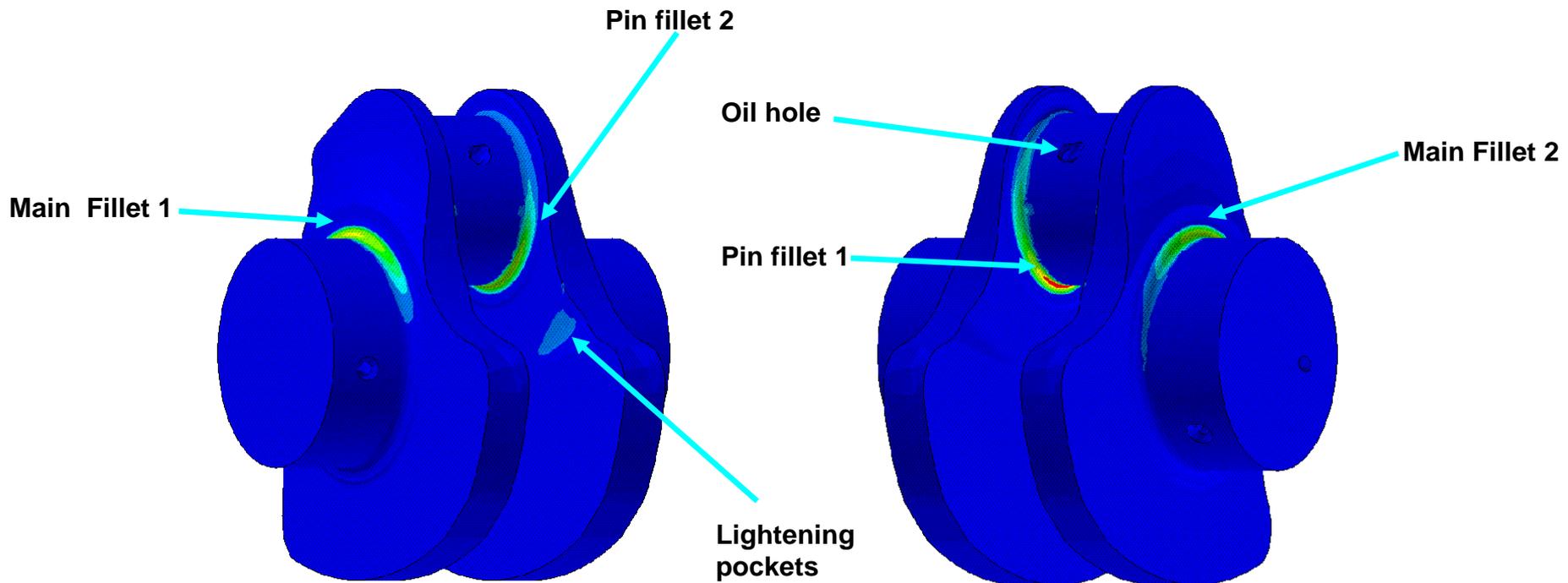
$$\sigma_{i,j,k,m,s} = \sum_n F_{k,n} C_{\sigma n i,j,m,s}$$

三维有限元给出的单位载荷节点应力线性叠加，权重是曲轴设计分析给出的力和力矩

- $C_{\sigma n}$ = stress factor (nodal stress for unit load F_n)
- F_n = Instantaneous force or moment
- n = unit load case index
- i = stress tensor index
- j = FE node index
- k = crank angle (step) index
- m = stress concentration zone index
- s = solution (crankthrow) index

EFR 应力/疲劳法

对于多个应力集中区域分别输出EFR应力、疲劳可靠性



Courtesy of Cummins, Inc.

集成应用(与其它GT-SUITE库)

配气定时驱动

- 对配气机构动力学的影响
- 与凸轮轴扭振的相互影响
- 与齿轮、链条或皮带传动装置动力学的相互影响

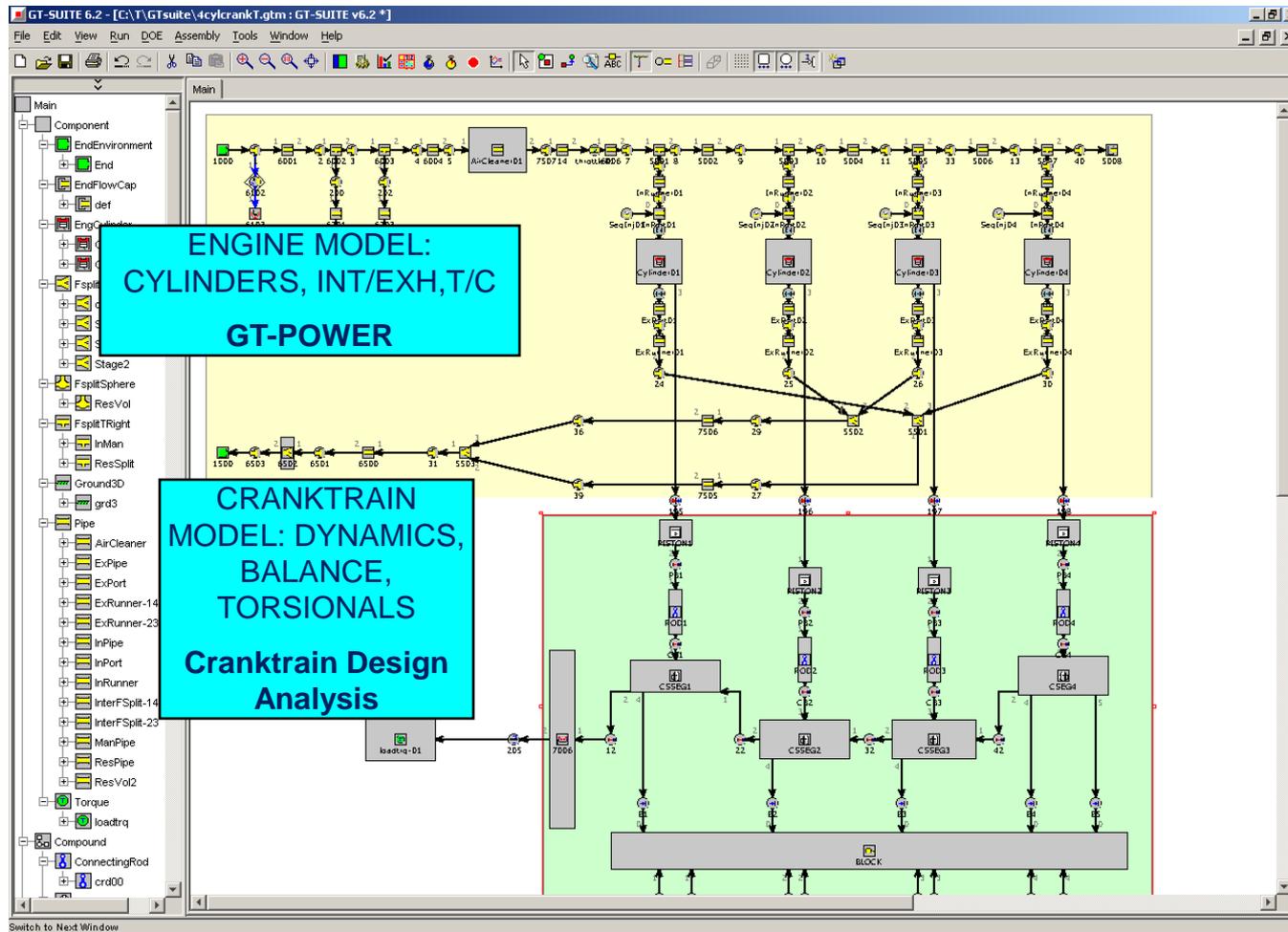
发动机性能

- 与气缸热动力学的相互影响
- 缺火效果，缺火检测
- 燃烧变化
- 缸-缸变化
- 发动机瞬态
- 基于容积效率的点火顺序优化
 无需简化扭振（动力学）

车辆与动力系统

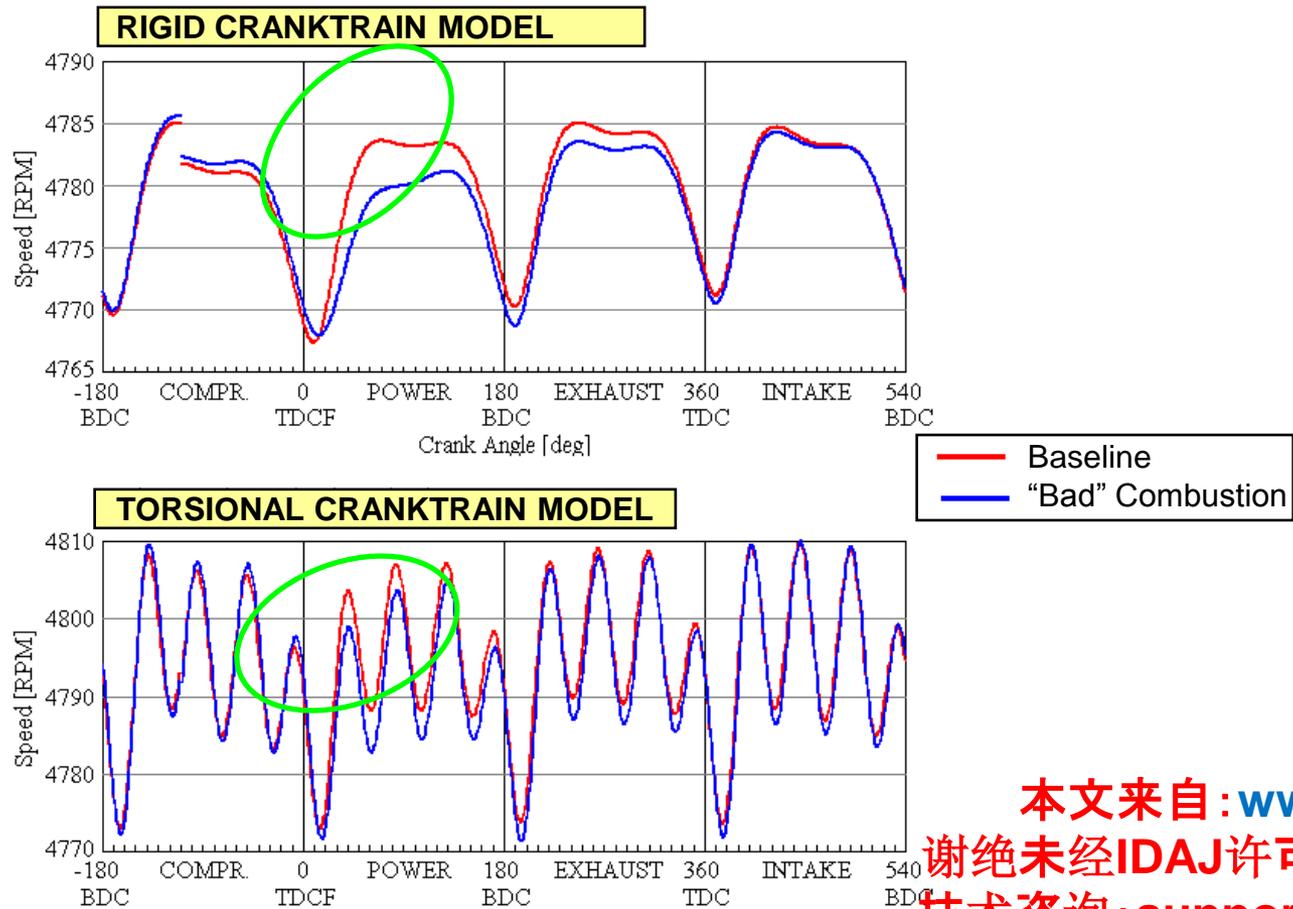
- 扭转减震器（隔振器）的分析与设计
- 对于动力系统组件和扭转动力学的影响，或缸体三维振动对于车辆尤其是瞬态情况下的影响

发动机性能和曲轴/缸体动力学联合模型



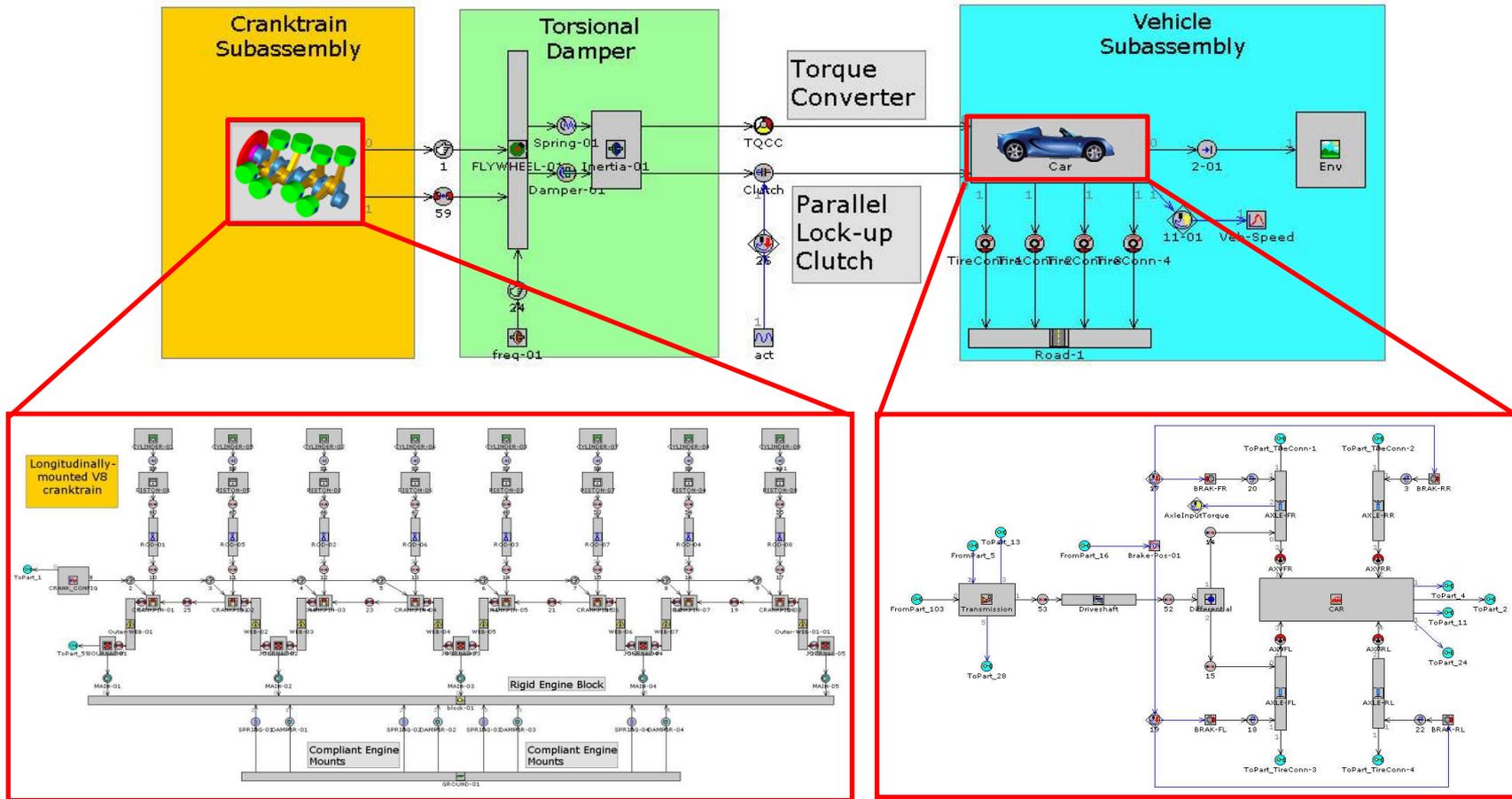


一缸中发生“坏”燃烧对于发动机转速的影响 - 5000 RPM

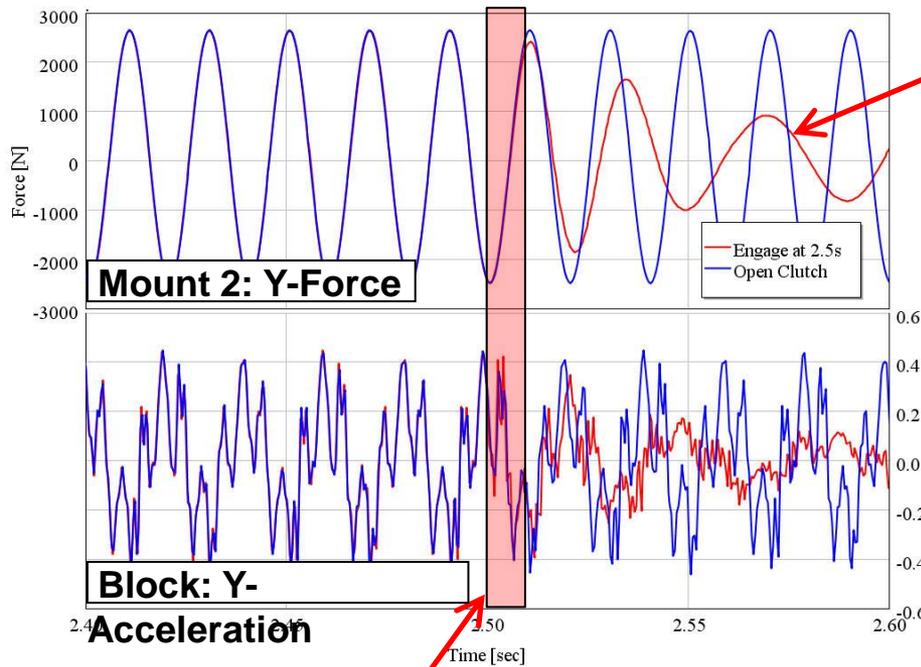


本文来自: www.idaj.cn
 谢绝未经IDAJ许可的转载!
 技术咨询: support@idaj.cn

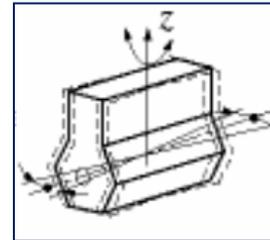
GT-SUITE模型：传动机构+曲轴+支架系统



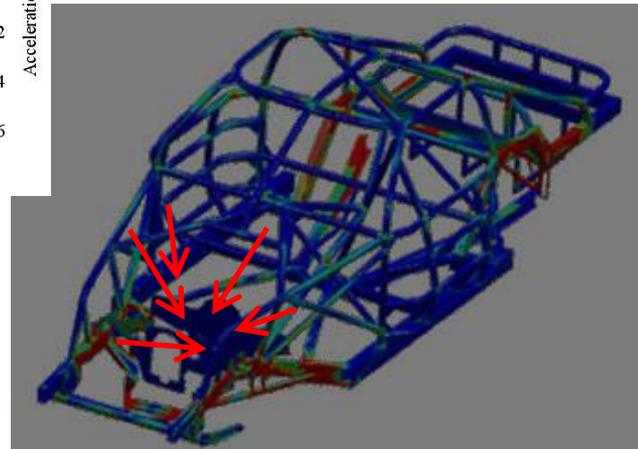
发动机缸体支架系统对离合器锁止的响应



Lower freq. due to engaged vehicle+driveline inertia



Engine mount locations on chassis



TC Lockup clutch engagement

GT-SUITE predicts engine mount forces for vehicle chassis dynamic FEA



主要优势

GT-SUITE的高度集成性

- 行业内唯一完全集成的软件，单一GUI，单一求解器，非传递耦合求解
- 曲轴分析、传动系统、发动机分析、燃料系统、液压系统等均可集成求解

具有优化功能

- 具有DOE和优化求解功能

其它优势

- 并行后处理功能
- 内置Simulink控件库
- 广泛的适用性，能处理基本所有发动机配置类型
- 快速计算，通过多种算法改进提升计算速度
- 无需单独License
- 三维参数建模（开发中）



GT-SUITE

配气机构分析



GT-SUITE配气机构分析亮点

升力曲线法设计凸轮廓线

配气机构动力学，凸轮设计

配气机构准动态分析

配气机构多体，弹性动力学分析

配气机构摩擦(赫兹接触, 弹流润滑分析)

液压元件（液压间隙调节器，凸轮相位器）和电路

凸轮轴扭振，多缸模型

凸轮轴弯曲和凸轮轴轴承油膜

液压电路和泵的集成模型

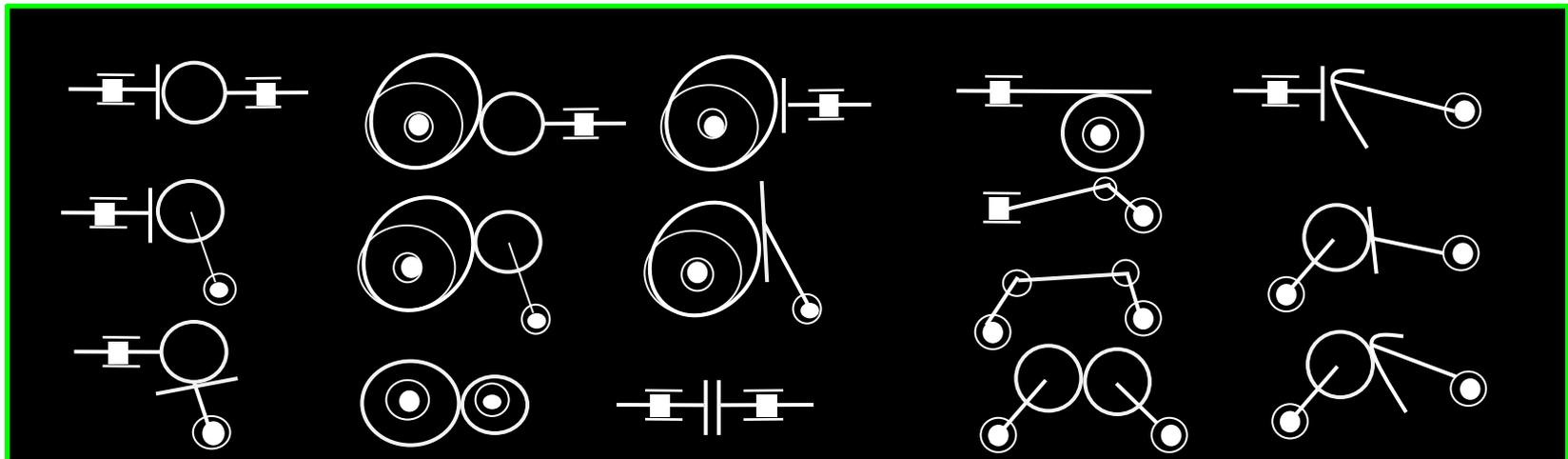
曲轴和正时传动机构的集成模型

VTDesign

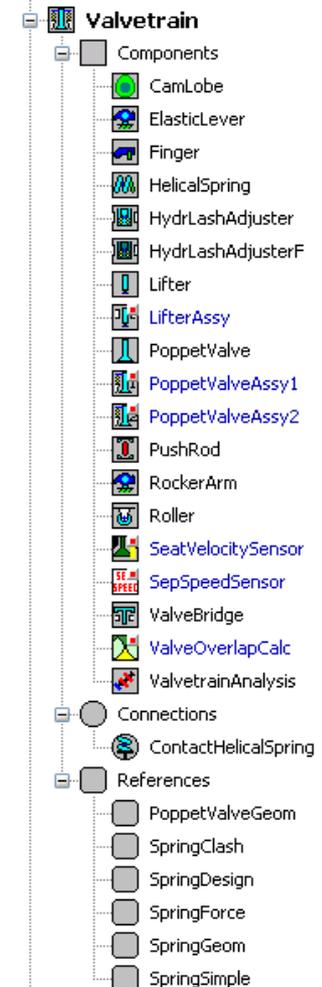
本文来自：www.idaj.cn
谢绝未经IDAJ许可的转载！
技术咨询：support@idaj.cn

通用平面动力学库

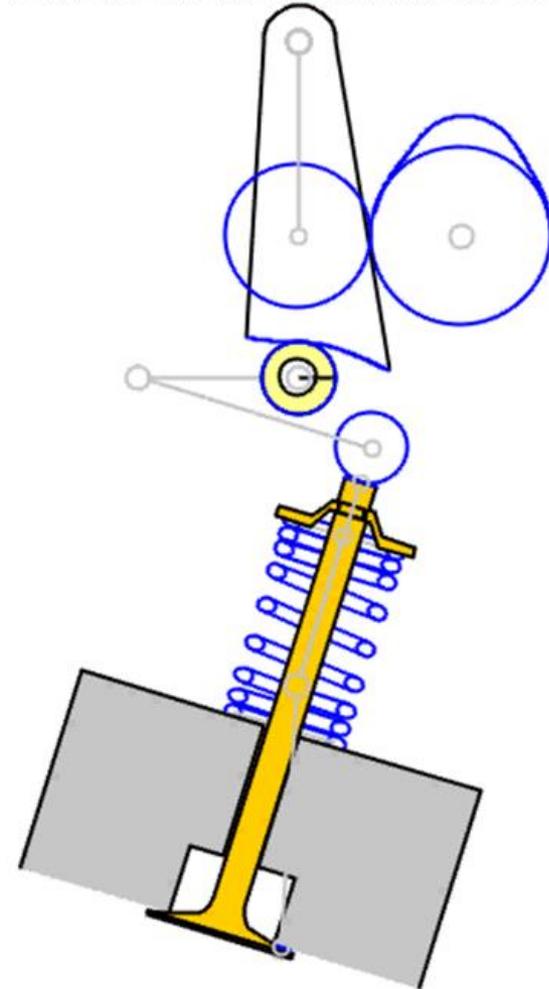
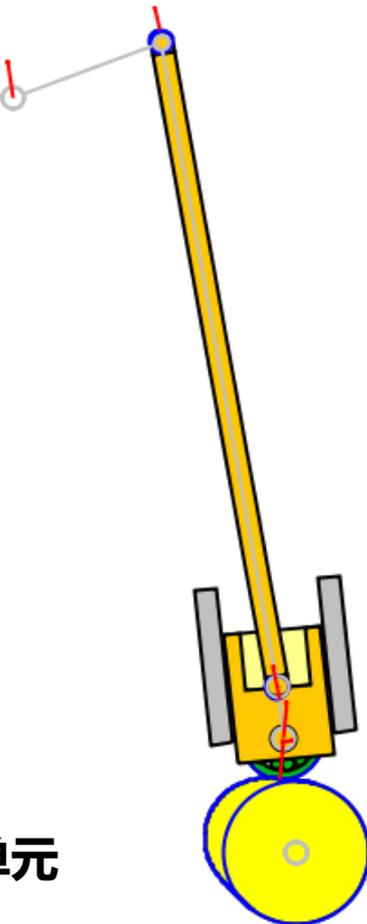
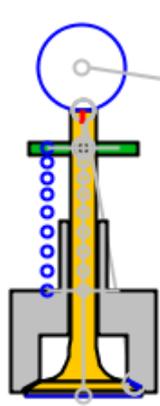
- 线性和旋转自由度
- 所有常见平面运动操作
- 凸轮凸角（或接触面）求解选项，包括摇摆摆动凸轮
- 可用于任何平面机构建模
- 所有运动操作均允许有间隙
- 详细的输出和动画



配气机构应用库

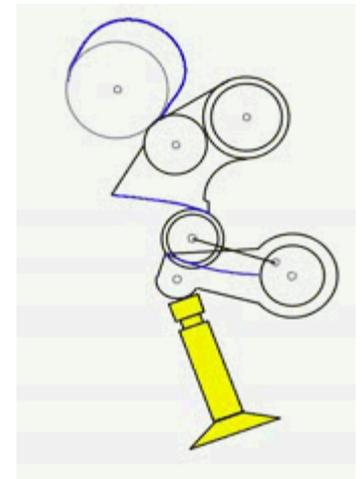
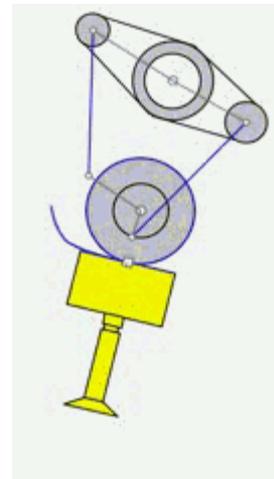
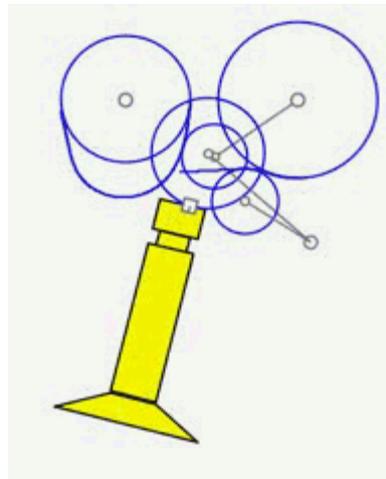
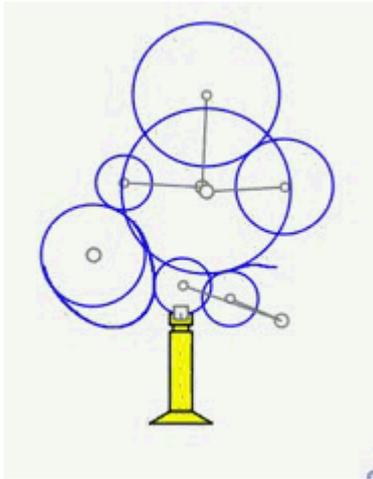


部件几何图形显示

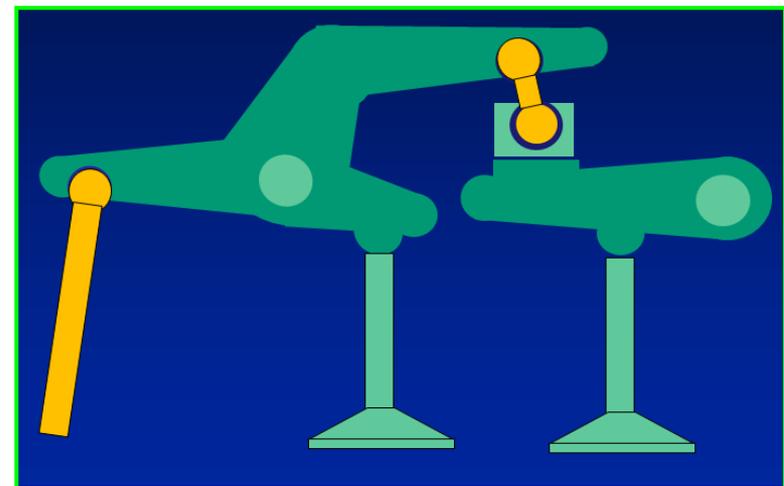
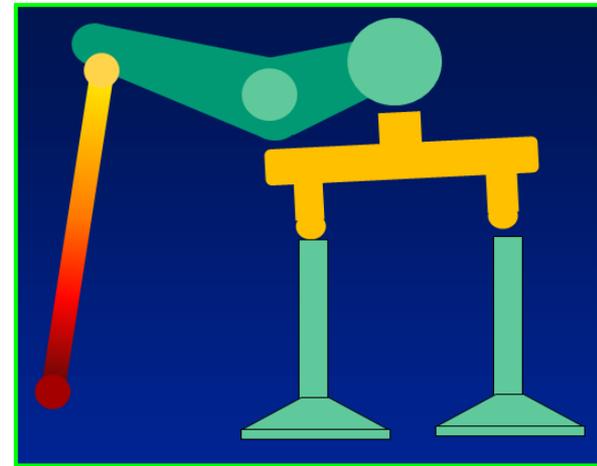
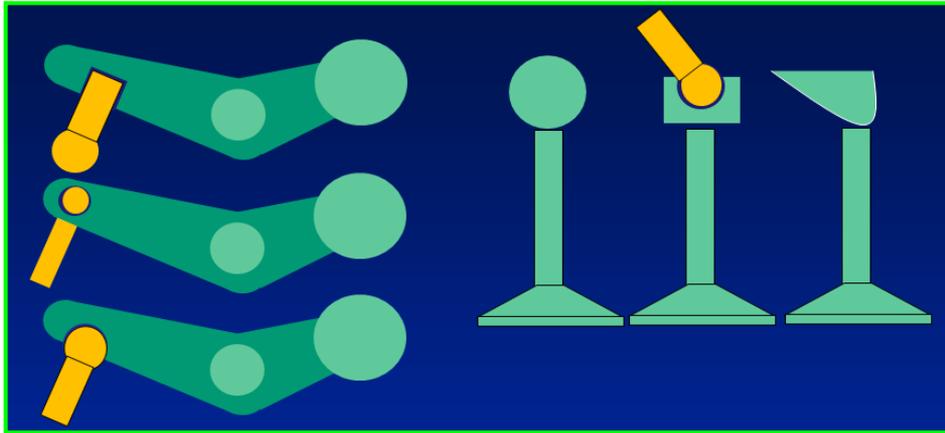


模型显示和动画
内置于配气机构库单元

动画显示

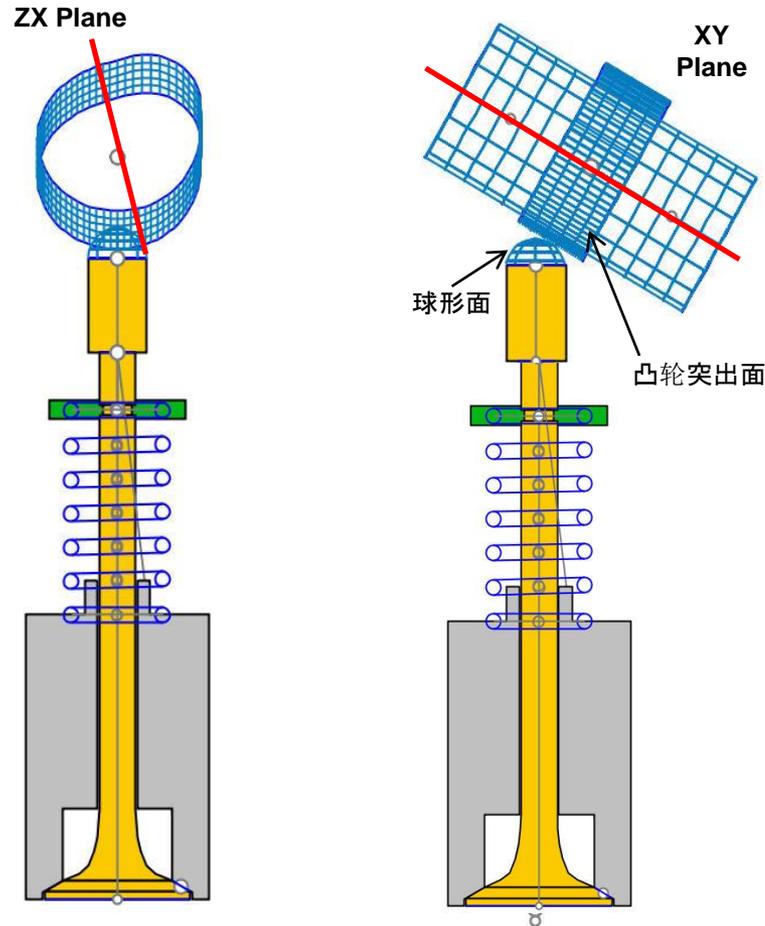


通用配气机构配置



- 任意和所有类型的接触和接头
- 非传统单元(更多的杆和滑动部件)
- ‘内置’螺旋弹簧，液力间隙调节器
- 倾斜舱，“象足”
- 双凸轮，连控轨道
- 双摇杆
- 无阀桥
- 离面（三维）推杆
- 三维模型

三维模型案例：凸轮和挺杆之间的离面接触



三维模型案例：离面阀桥

对于离面角度 $> 15 - 20^\circ$
的情况可能需要三维的阀
桥模型

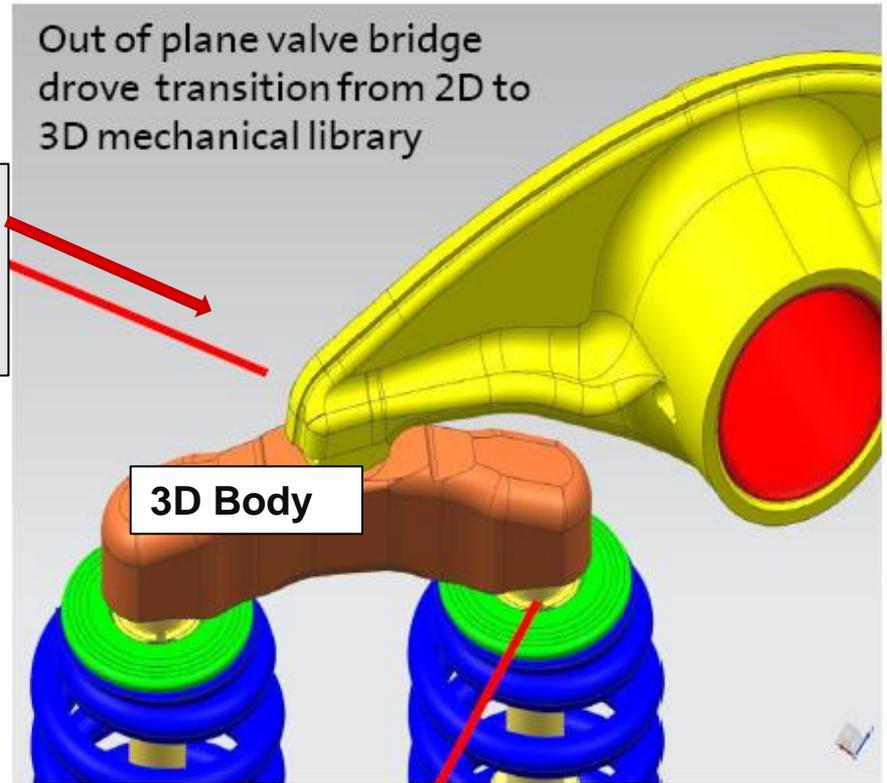
和三维模型间的过渡只在
需要的地方进行

尽量减少对CPU计算时间
的影响

Courtesy of GM Powertrain

Transition
by 2D-3D
contact
model

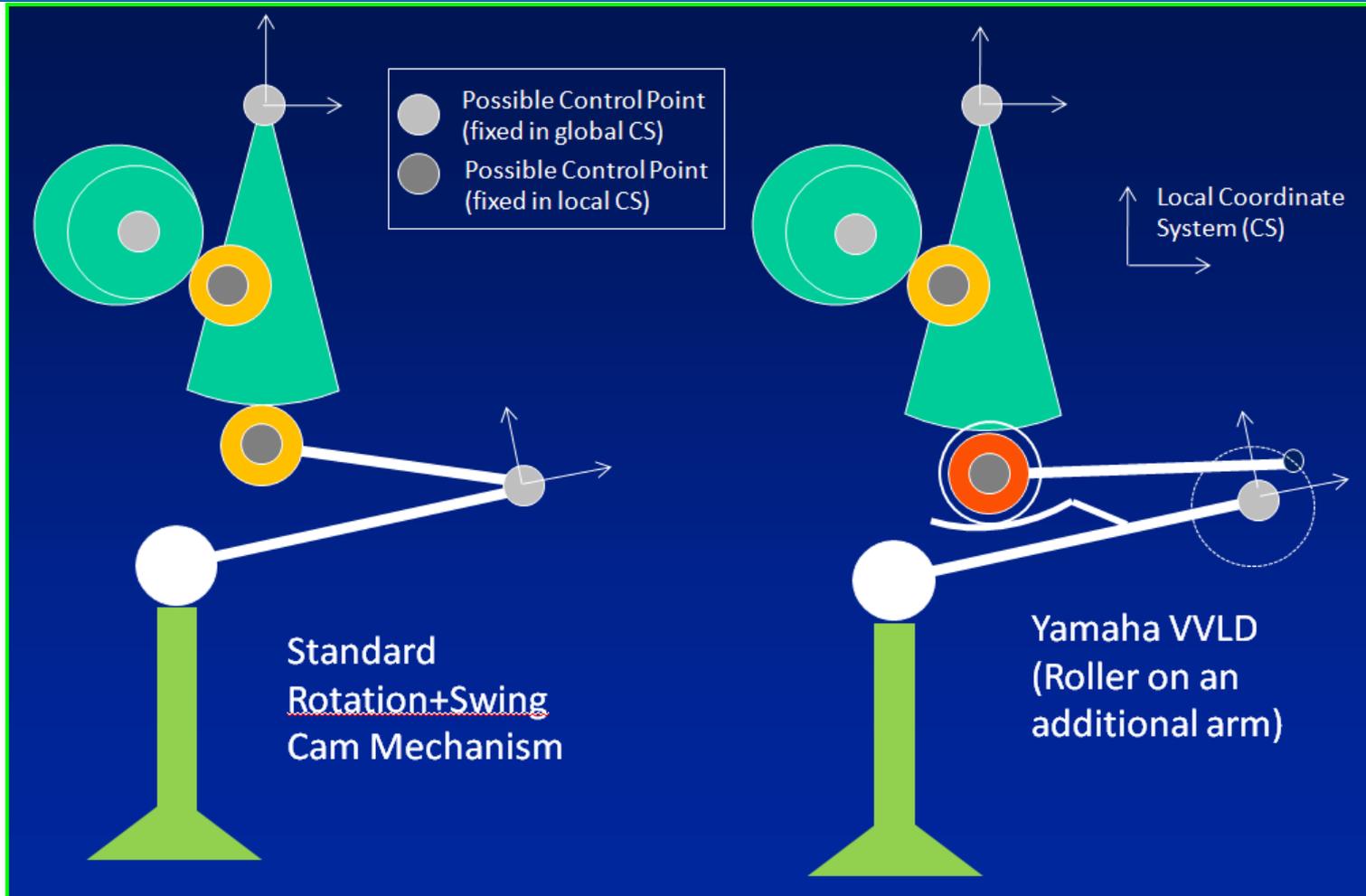
Out of plane valve bridge
drove transition from 2D to
3D mechanical library



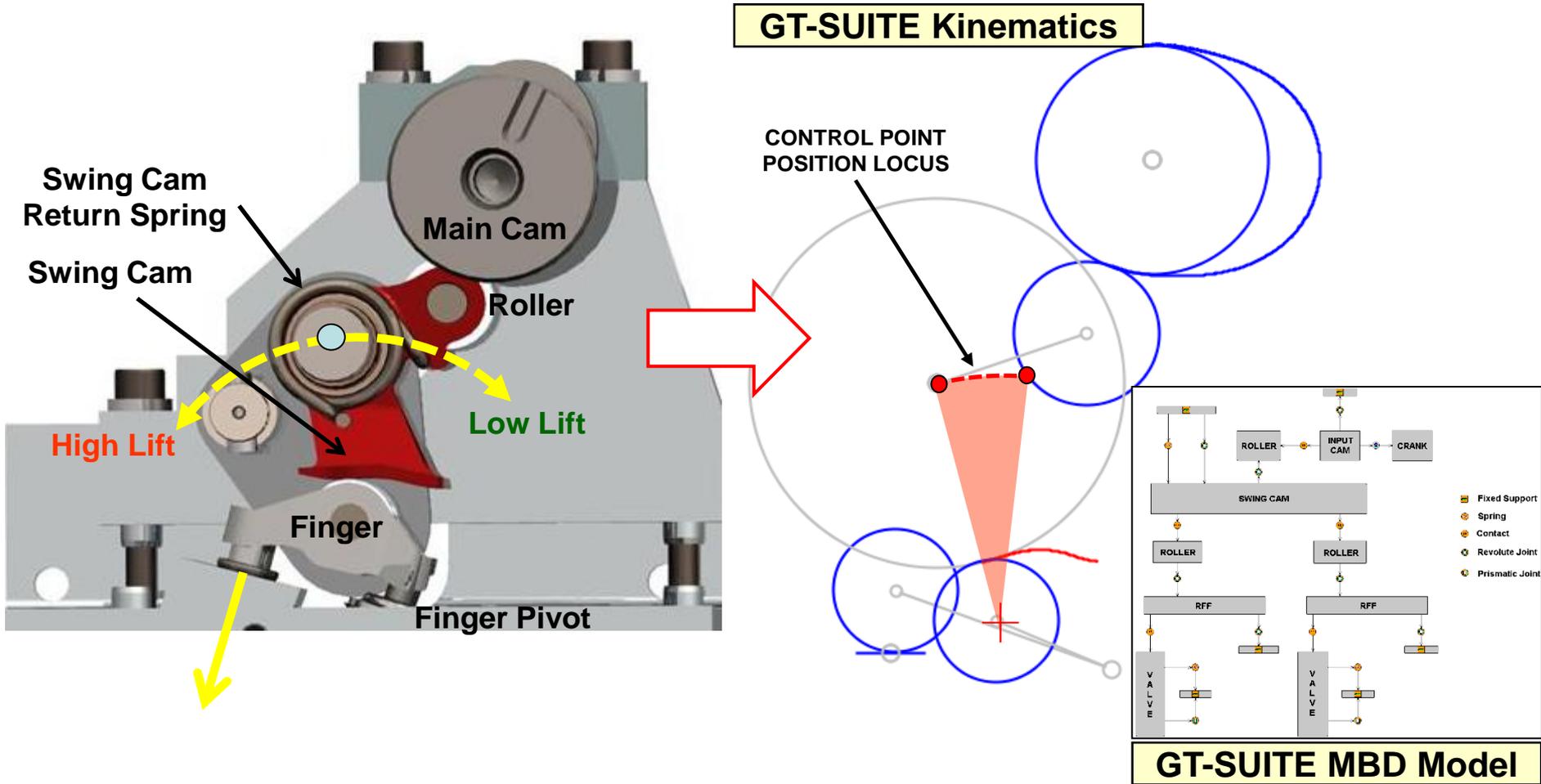
3D Body

Transition from
3D back to 2D at
the valve stem tip

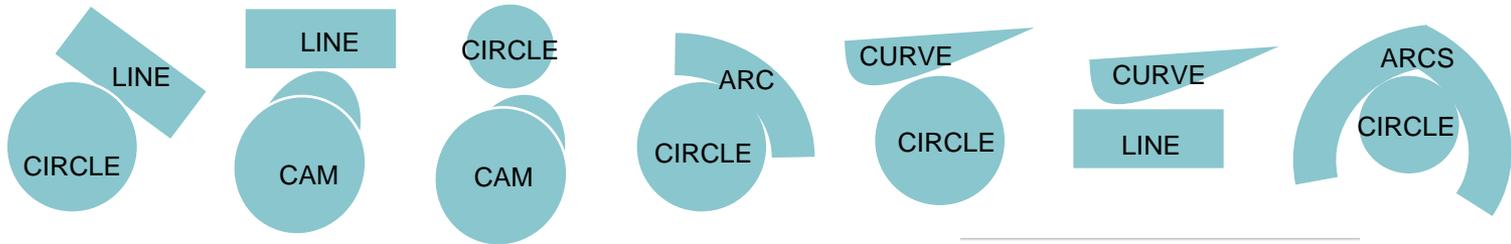
机械式VVA配气机构案例：摆动凸轮配置



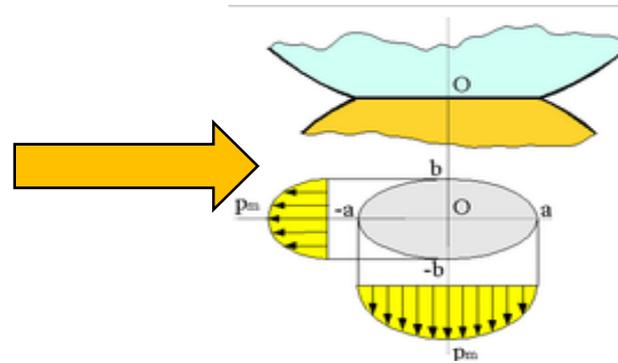
Delphi连续可变气门升程(CVVL)配气机构



通用接触(二维平面)



- 对所有类型接触做赫兹接触及弹流润滑分析 并输出
- 可选: 接触作为切线约束 (无分离, 在某些分析中 useful)

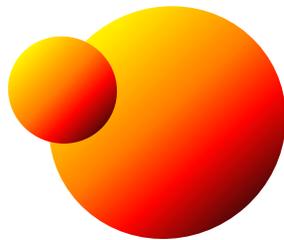


Attribute	Unit	Object Value
Enforce Contact Constraint?		<input checked="" type="checkbox"/>
Velocity Constraint Stabilization Factor	1/s	def ...
Displacement Error Stabilization Coefficient	1/s	def ...

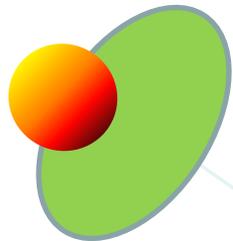
本文来自：www.idaj.cn
谢绝未经IDAJ许可的转载！
技术咨询：support@idaj.cn

通用接触(三维)

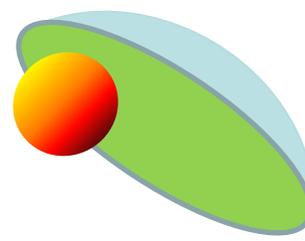
- 和二维接触相同模型，采用三维动力学
- 凸球面和平面或凹面之间的接触，以及球面、柱面、锥面、凸轮面在三维空间中任意朝向的接触



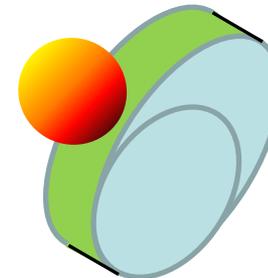
SPHERICAL
(OUT)



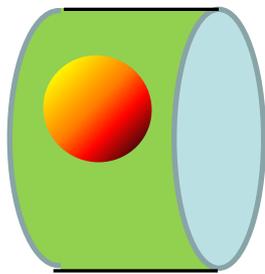
FLAT



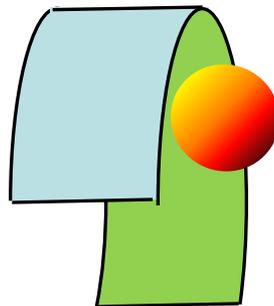
SPHERICAL
(IN)



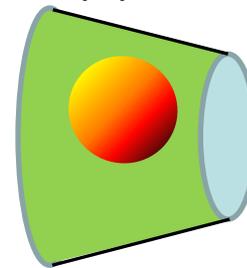
CAM
LOBE



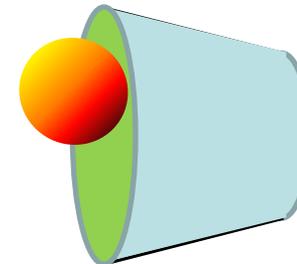
CYLINDRICAL
(OUT)



CYLINDRICAL
(IN)

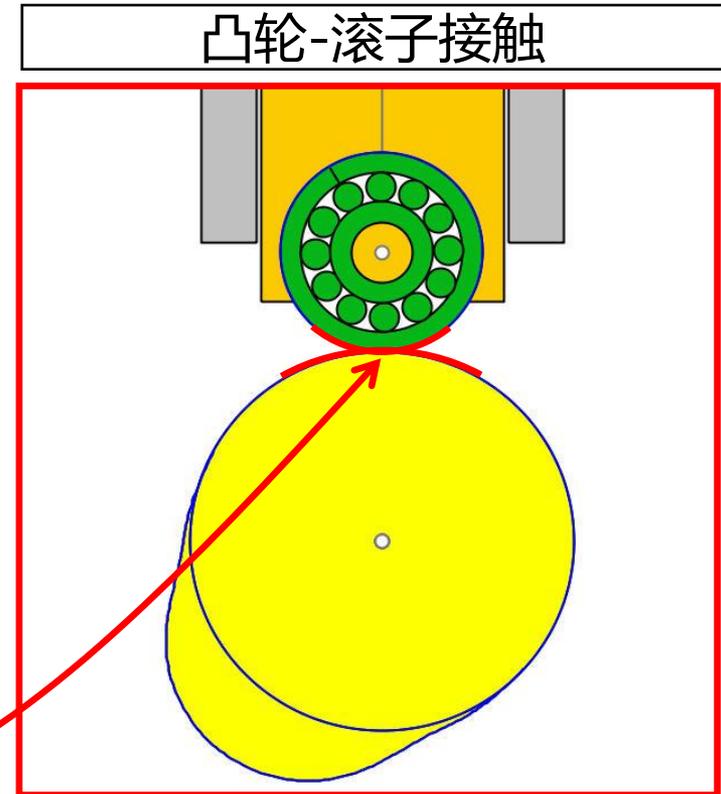
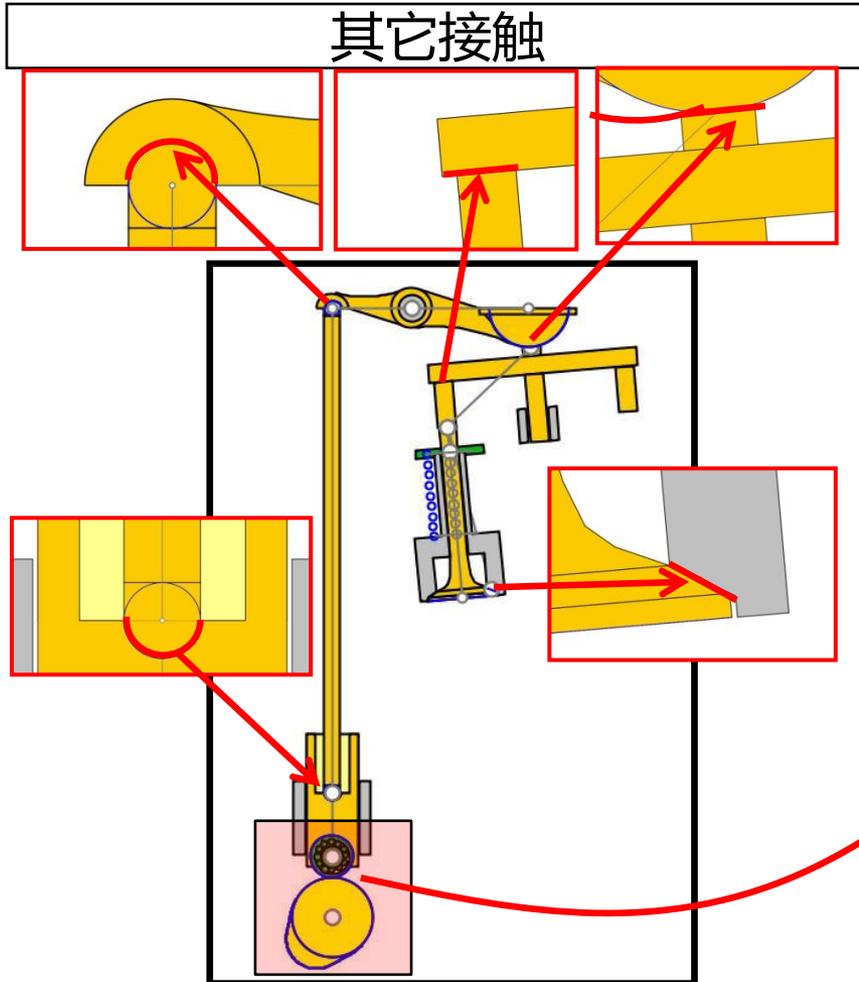


CONICAL
(OUT)



CONICAL
(IN)

典型配气结构接触分析(推杆气门)





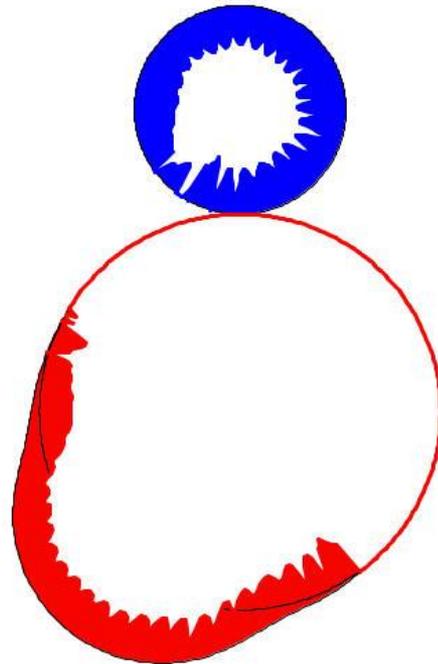
接触摩擦输出(包含弹流润滑和粗糙度分析)

- 接触法向力
- 接触摩擦力(包括流体接触和表面粗糙接触)
- 卷吸速度
- 最大赫兹应力
- 接触最大变形
- 接触区尺寸(椭圆直径)
- 油膜厚度
- 粗糙接触压力
- 有效刚度
- 最大赫兹应力 (表面分布)
- 磨损载荷 (表面分布)

接触摩擦输出

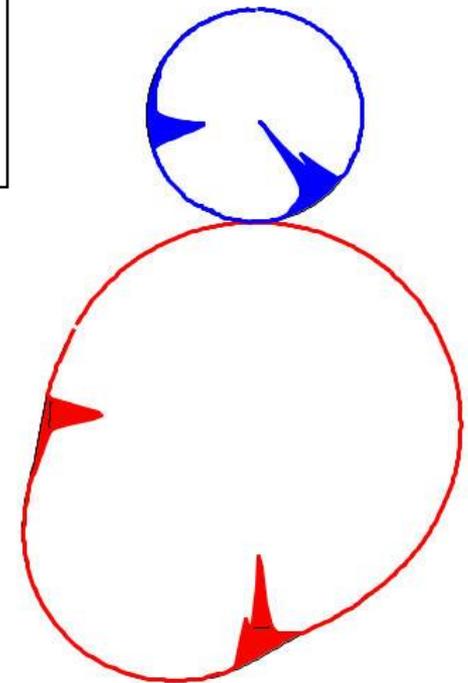
最大赫兹应力表面分布

Maximum Hertz Stress = 1656.4 Mpa



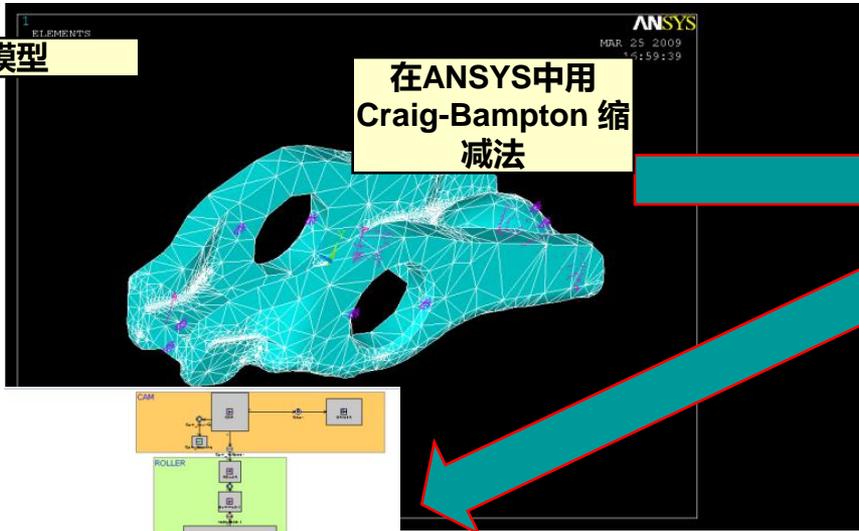
平均磨损载荷表面分布

Avg. Wear load = average of scrub velocity times metal-metal contact normal force, per unit area of surface, over engine cycle



用有限元/超单元模拟配气机构指状随动轮

ANSYS模型



输入质量、阻尼和刚度矩阵给GT-SUITE超单元部件

EDIT Object: suel-01

Template: SuperElement

Object: suel-01

Comment:

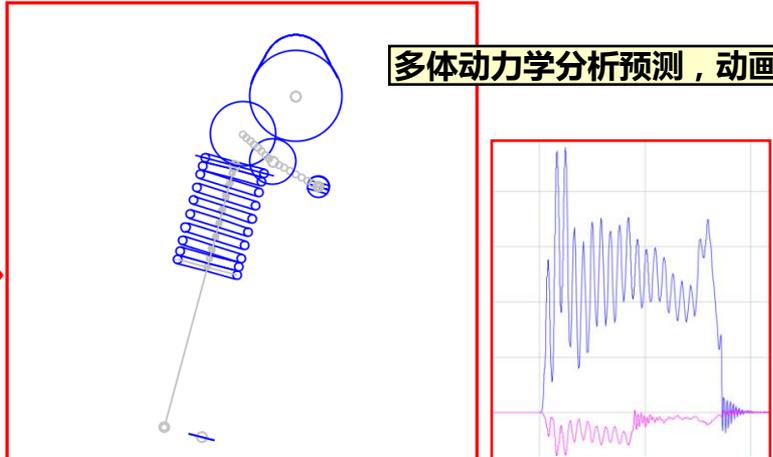
Mass...	1	2	3	4	5	6	7
1	7.0515E-4	5.8451E-4	2.162E-5	9.2118E-4	1.201E-5	1.0327E-4	-1.4642E-4
2	5.8451E-4	0.0193238	2.8742E-4	3.6083E-4	6.8078E-4	-9.327E-5	-1.8907E-4
3	2.162E-5	2.8742E-4	8.6434E-4	-1.0703E-4	-2.858E-5	2.858E-4	1.9751E-4
4	9.2118E-4	3.6083E-4	-1.0703E-4	5.2898E-4	1.1105E-4	2.469E-5	-1.6091E-4
5	1.201E-5	6.8078E-4	-8.28E-6	1.1105E-4	9.7168E-4	-2.7933E-4	2.932E-5
6	1.0327E-4	-9.327E-5	2.858E-4	2.469E-5	-2.7933E-4	4.552E-4	-2.613E-5
7	-1.4642E-4	-1.8907E-4	1.9751E-4	-1.6091E-4	2.932E-5	-2.613E-5	5.8901E-4
8	2.046E-5	-2.1764E-4	-7.175E-5	1.058E-5	-2.8396E-4	7.354E-5	1.5902E-4
9	-1.622E-5	-4.995E-5	4E-7	1.301E-5	-5.986E-5	1.574E-5	-2.235E-5
10	-9.745E-5	-2.833E-4	1.1786E-4	-1.0372E-4	3.52E-5	6.71E-6	5.2993E-4
11	-2.4662E-4	-6.5475E-4	-1.9373E-4	-1.5335E-4	-1.2855E-4	4.795E-5	3.4756E-4
12	-1.4104E-4	2.1205E-4	3.874E-4	-1.6304E-4	5.52E-5	-2.493E-5	7.032E-5
13	3.3843E-4	1.2659E-4	1.0239E-4	2.3357E-4	2.145E-5	4.505E-5	2.4048E-4
14	-2.452E-5	1.5817E-4	3.03E-6	-3.233E-5	1.072E-5	2.04E-5	-1.608E-5
15	5.4579E-4	9.4746E-4	5.4887E-4	3.0786E-4	8.259E-5	8.372E-5	-3.2793E-4
16	3.2643E-4	-1.6536E-4	3.633E-5	2.6549E-4	-2.941E-5	-1.078E-5	2.7959E-4
17	2.116E-4	7.0192E-4	1.1344E-4	8.052E-5	9.422E-5	1.1974E-4	1.1335E-4
18	-4.0838E-4	-8.5122E-4	3.9647E-4	-3.2762E-4	-2.243E-5	3.224E-5	3.6651E-4
19	3.4334E-4	3.431E-5	4.012E-5	3.4635E-4	3.738E-5	-4.892E-5	3.7388E-4
20	-5.207E-5	3.43E-5	3.818E-5	-3.567E-5	2.5086E-4	6.166E-5	-4.053E-5

Main | Initial Conditions | Local Boundary Positions (Local) | Mass Matrix | Damping Matrix | Stiffness Matrix

OK Cancel Apply

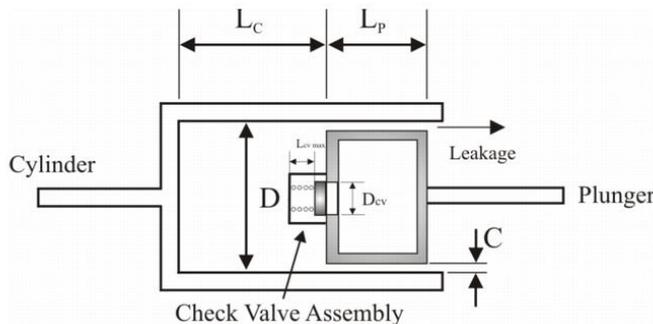
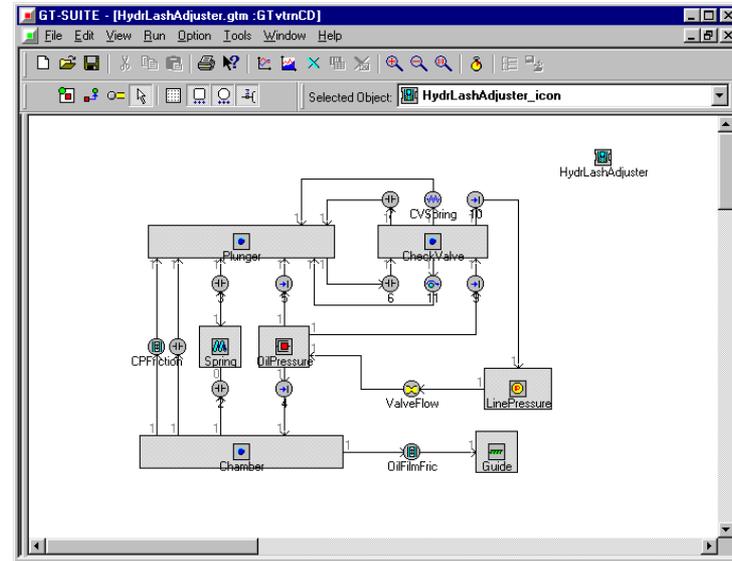
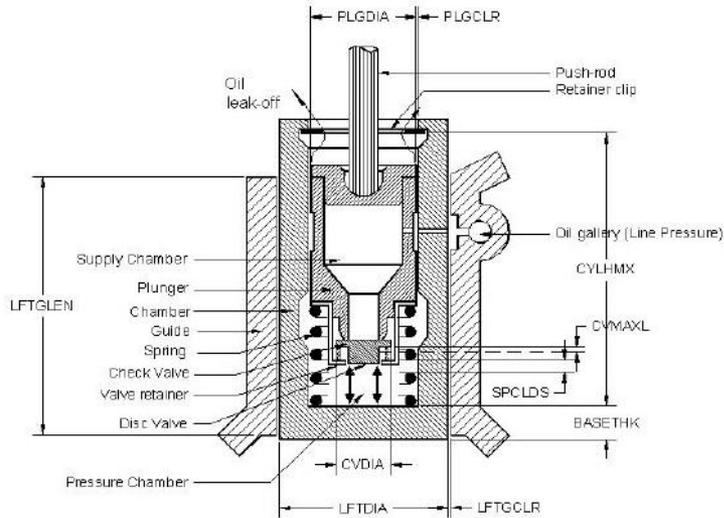
整个配气机构多体动力学模型，其中指状随动轮为超单元

多体动力学分析预测，动画

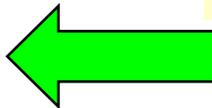




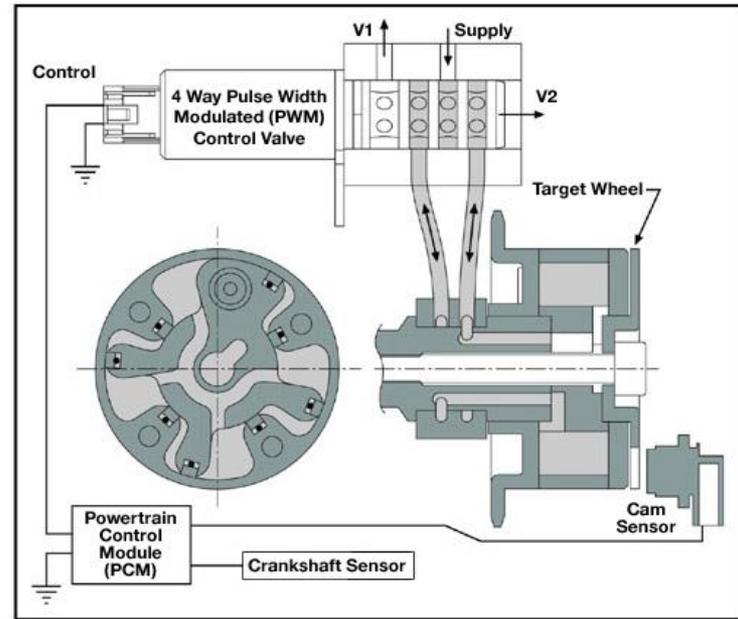
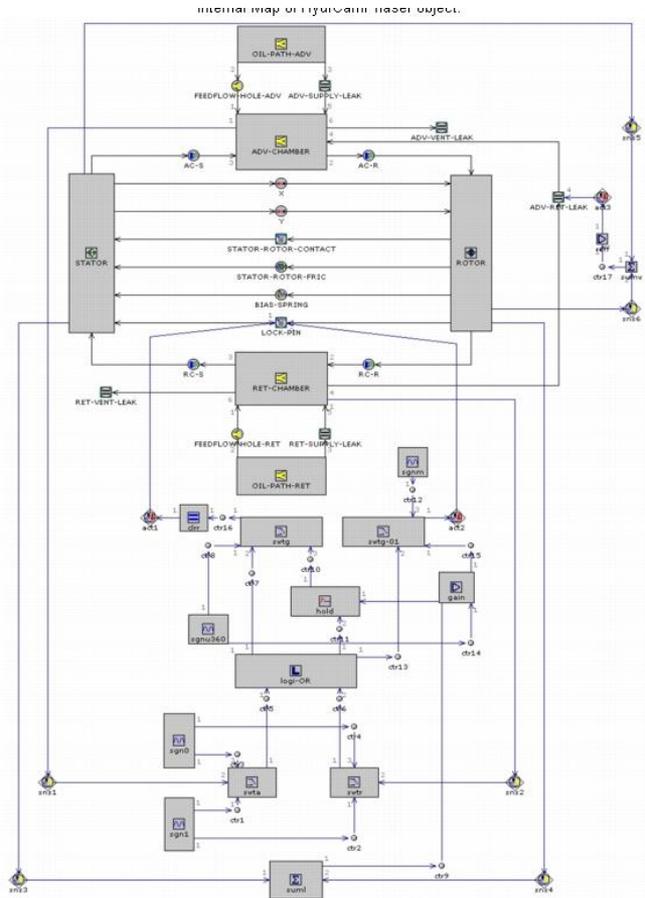
液力间隙调节器



液压系统可以用一维流动/液压库建模，并与多体动力学模型集成或者也可将基本液压元件作为一个“机械”的原型用于单独的多体动力学模型



叶片式液压凸轮相位器的流体机械模型



一种液压凸轮相位器的示意图

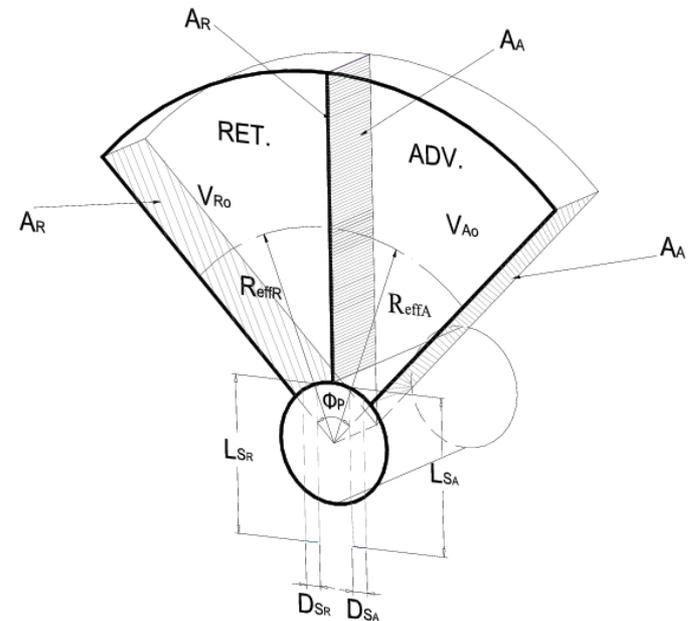
液压凸轮相位器的模型



液压凸轮相位器

详细流体机械模型:

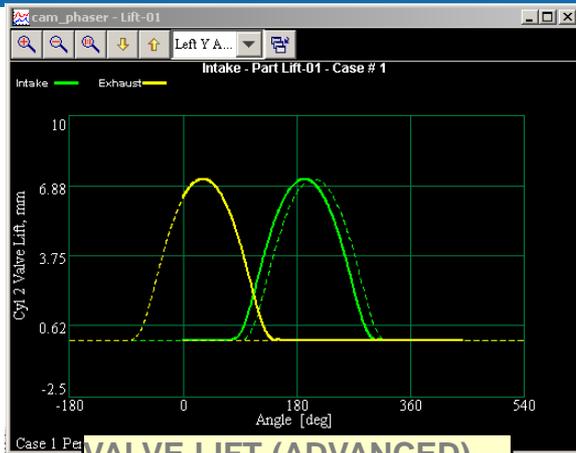
- 转子/定子惯性
- 提前和迟滞腔
- 漏泄通路
- 腔室和泄漏的流动端口
- 供给口和通道几何
- 锁钉
- 偏压弹簧
- 转子-定子摩擦



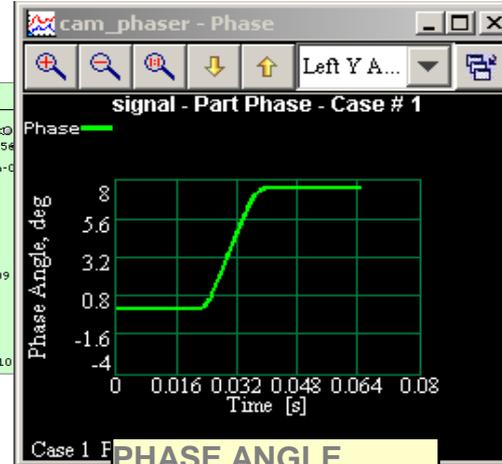
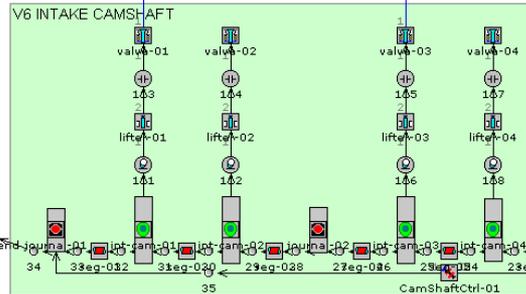
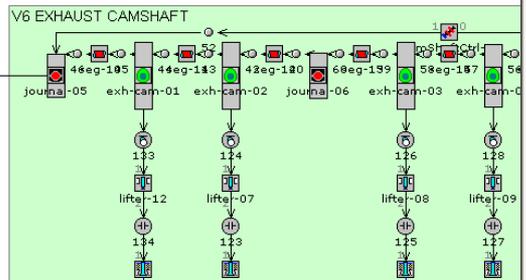
凸轮相位器腔室几何模型



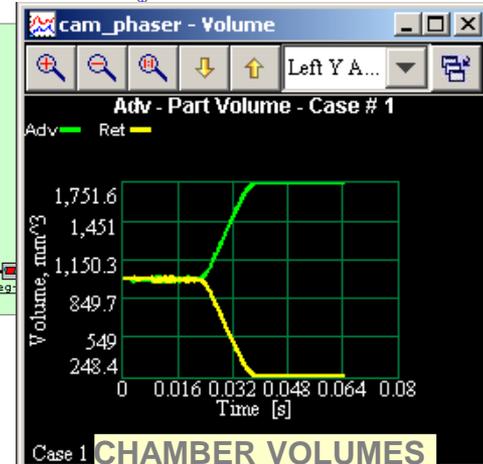
凸轮相位器模型与配气机构/凸轮轴耦合



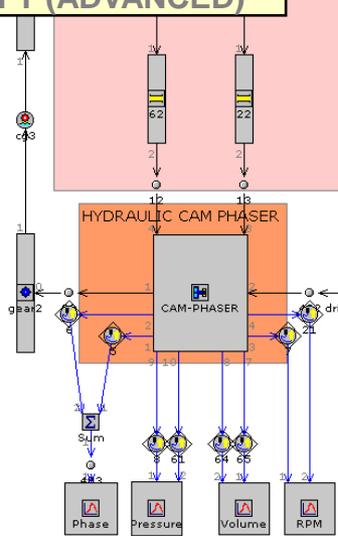
VALVE LIFT (ADVANCED)



PHASE ANGLE



CHAMBER VOLUMES



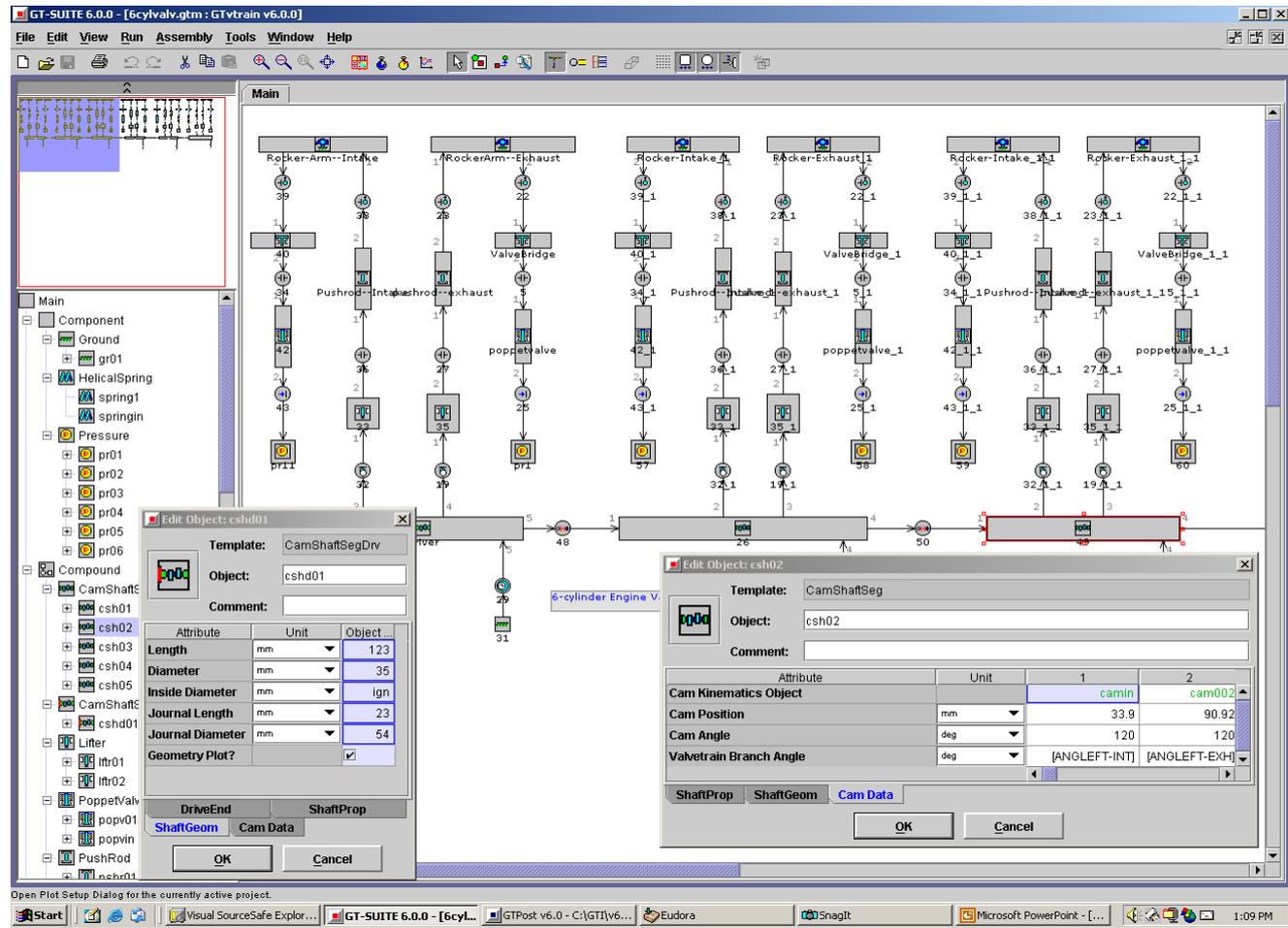


本文来自: www.idaj.cn

谢绝未经IDAJ许可的转载!

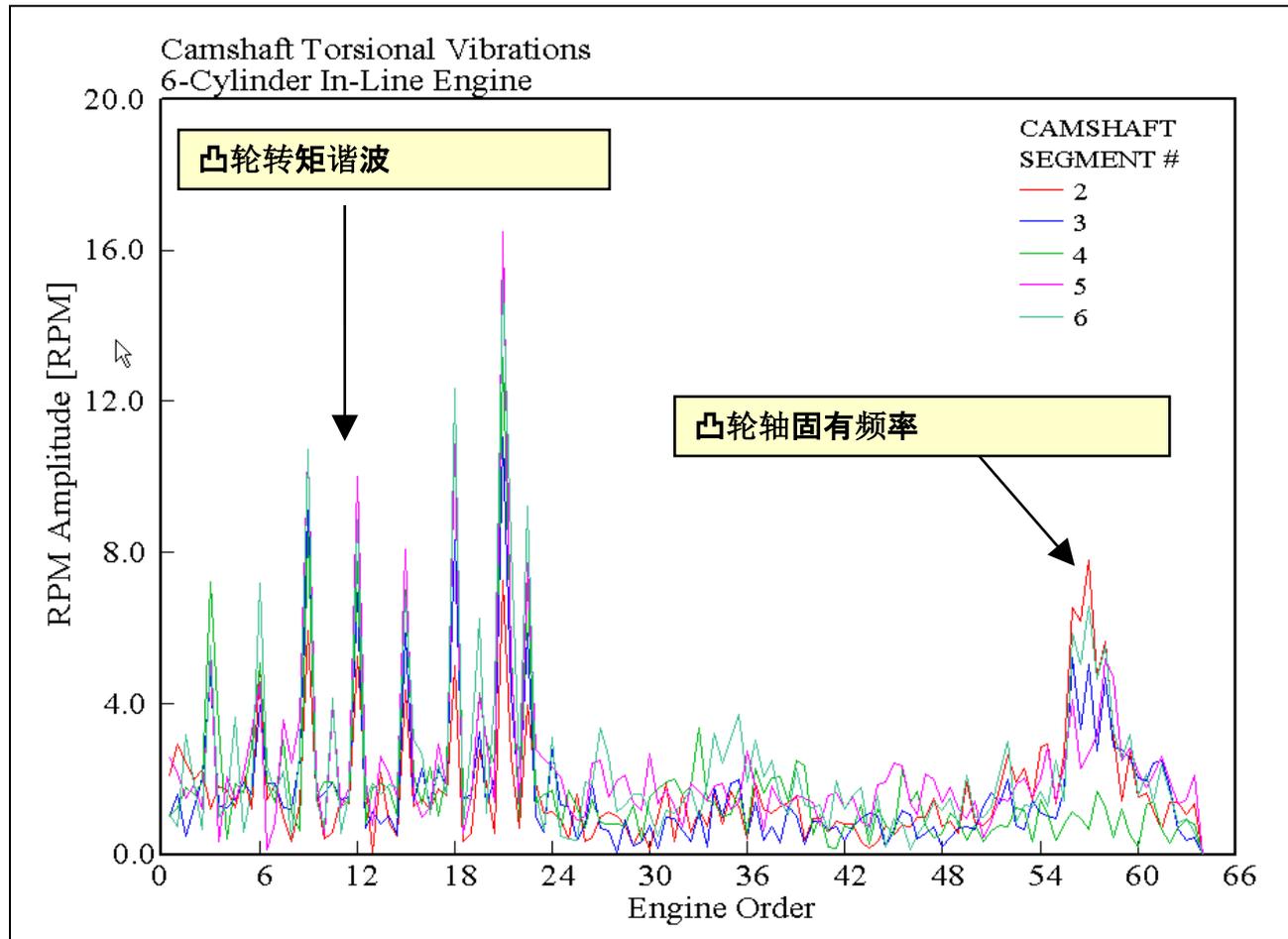
技术咨询: support@idaj.cn

6缸配气机构模型-凸轮轴扭振



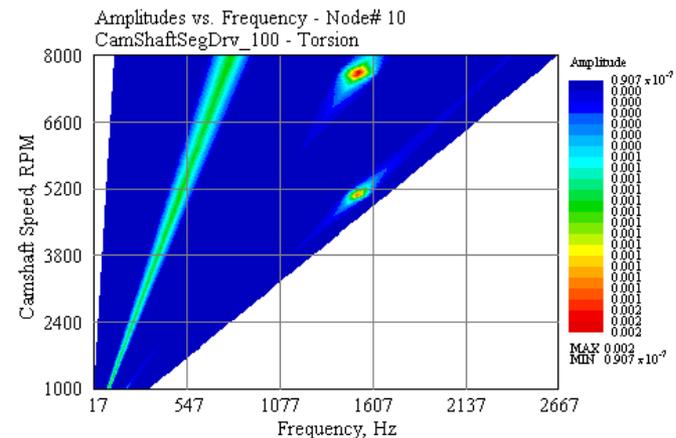
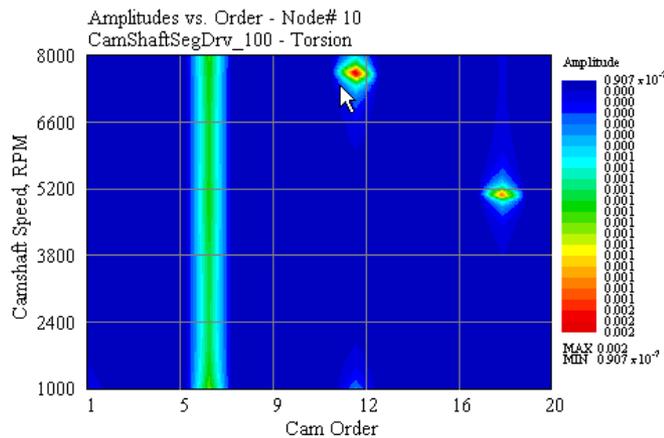
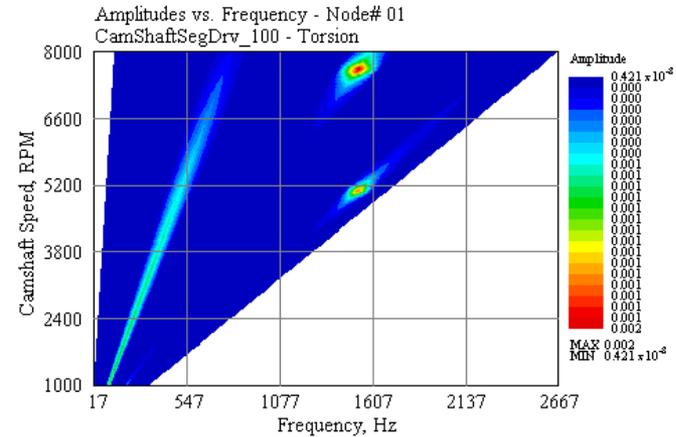
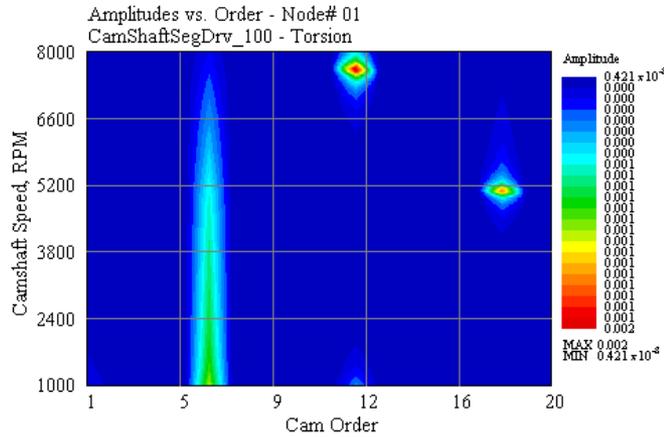


时域预测的谐波分析 (FFT) : 凸轮轴转速

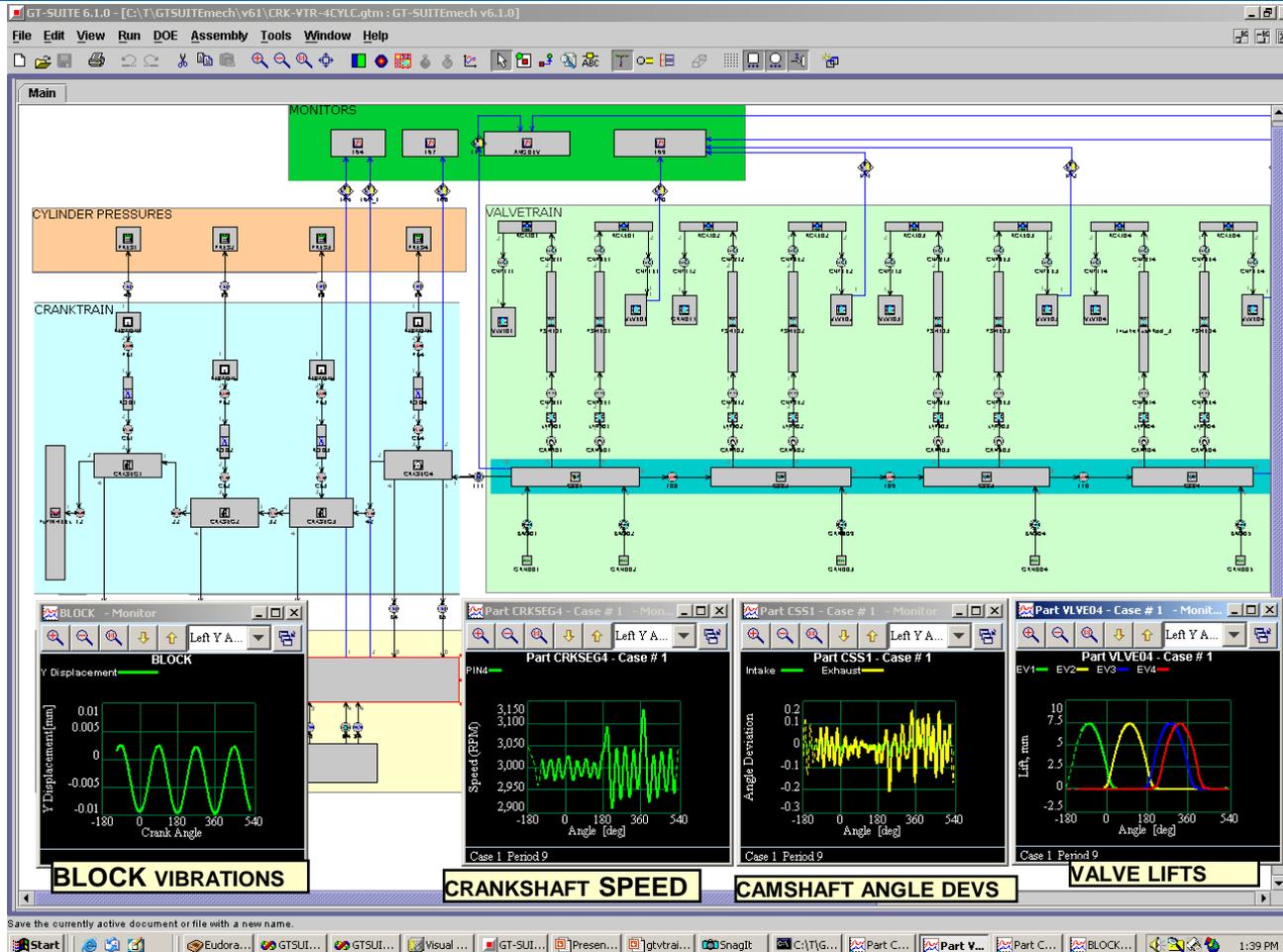




凸轮轴扭振-强迫振动分析



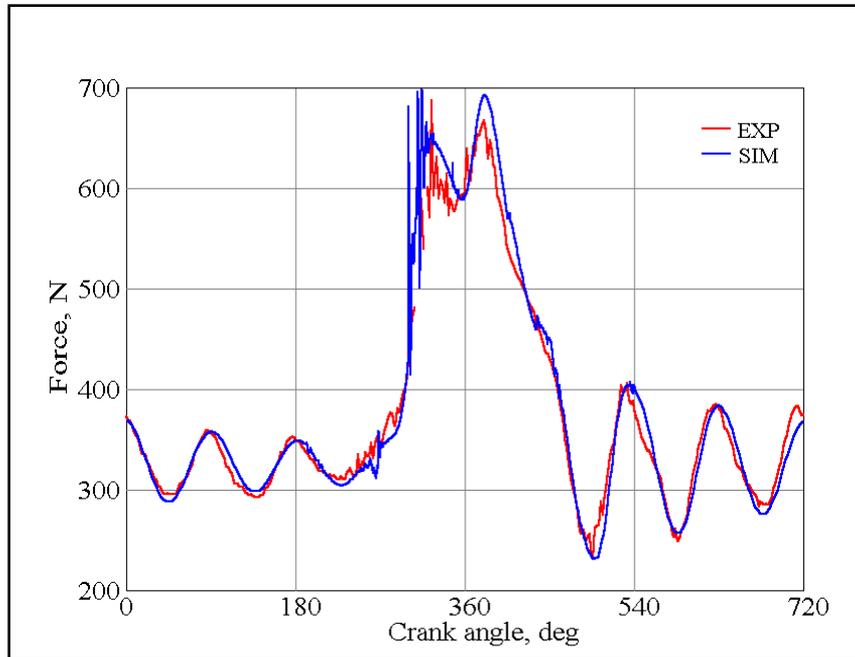
与曲轴及/或正时驱动模型集成



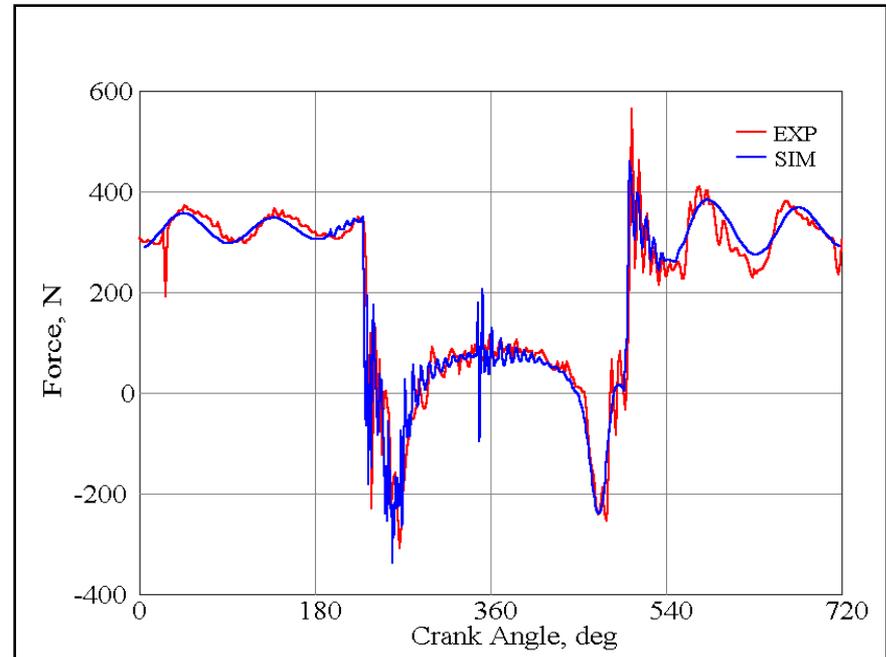


与实验测量对比

FORCE UNDER SPRING



VALVE NECK FORCE



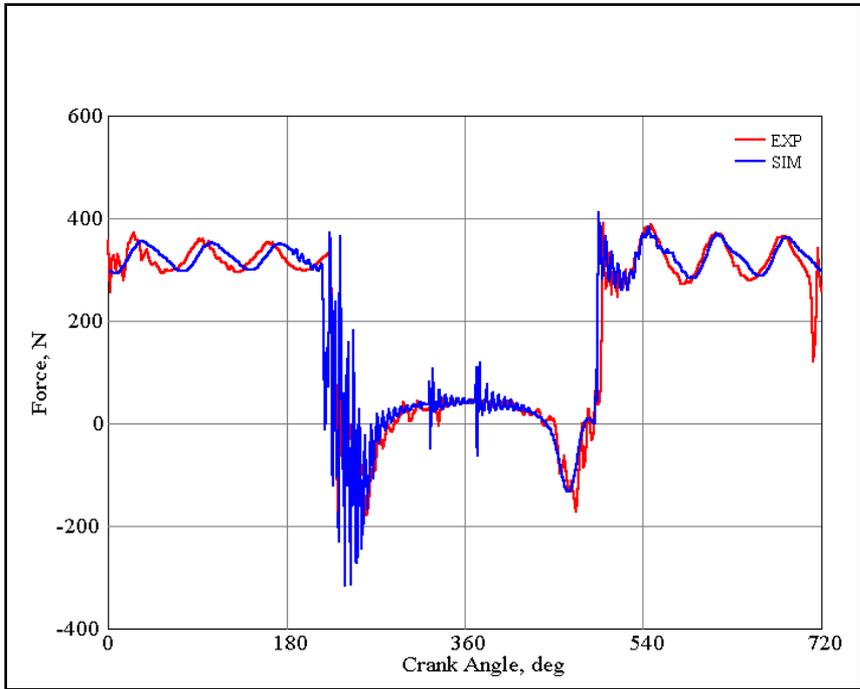
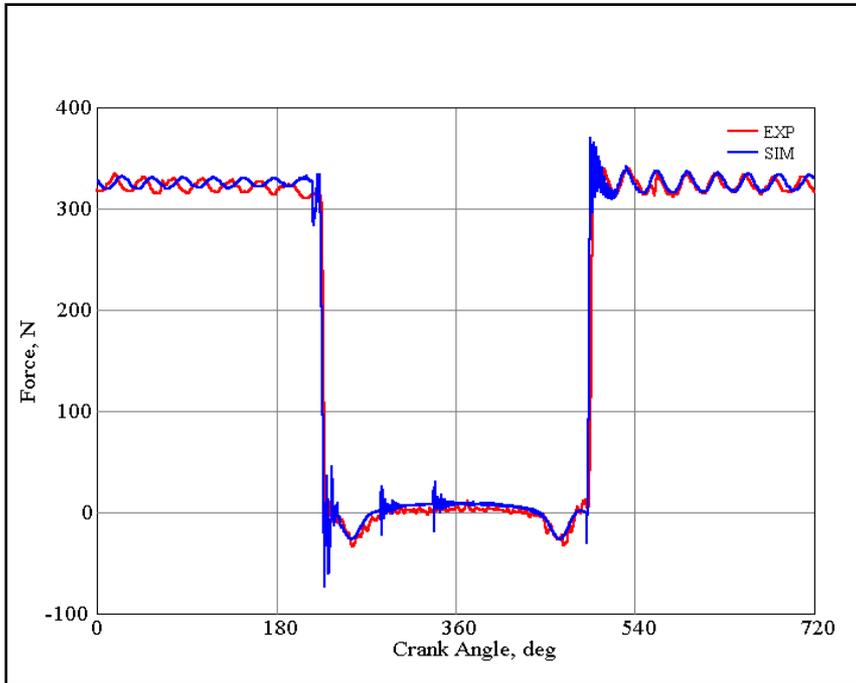
6000 RPM



与实验测量对比

2000 RPM

4500 RPM

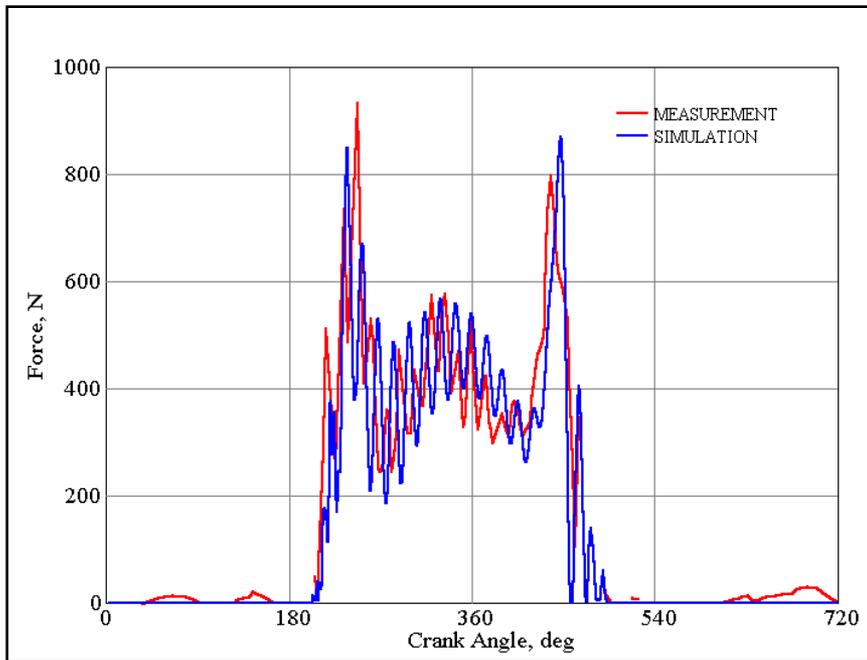


VALVE NECK FORCE

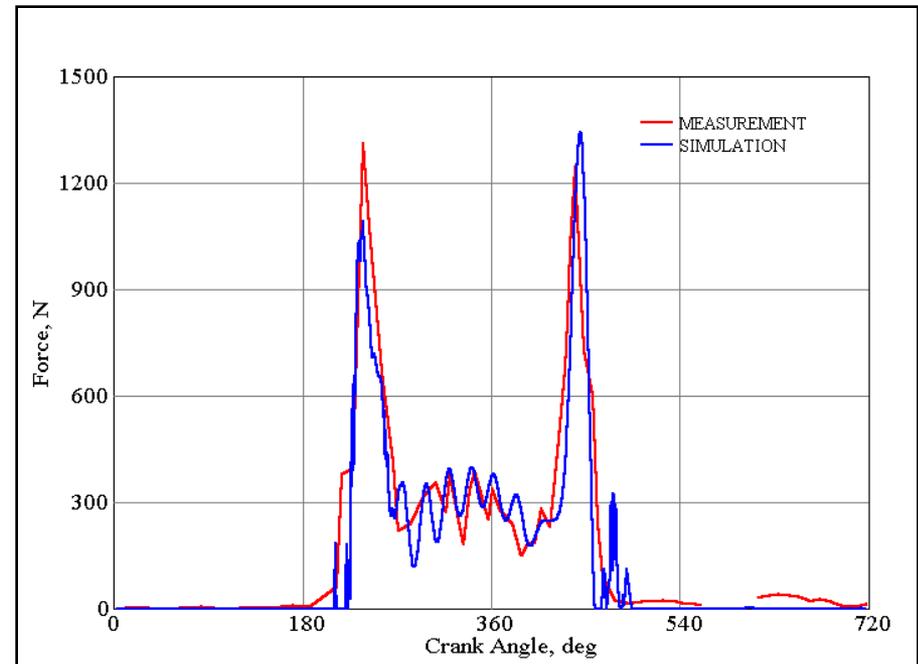


与实验测量对比

2200 RPM



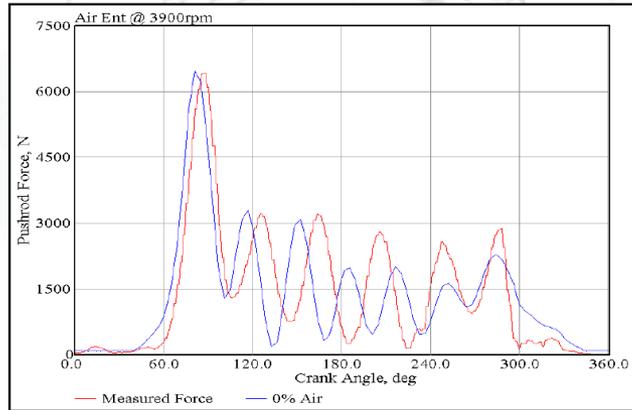
3200 RPM



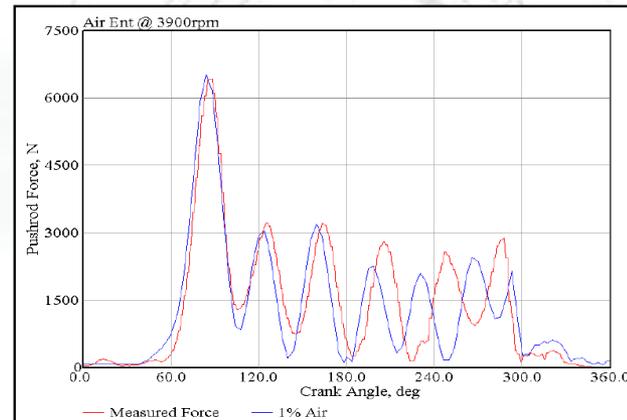
PUSHROD FORCE

配气机构及液力间隙调节器挺杆力校准

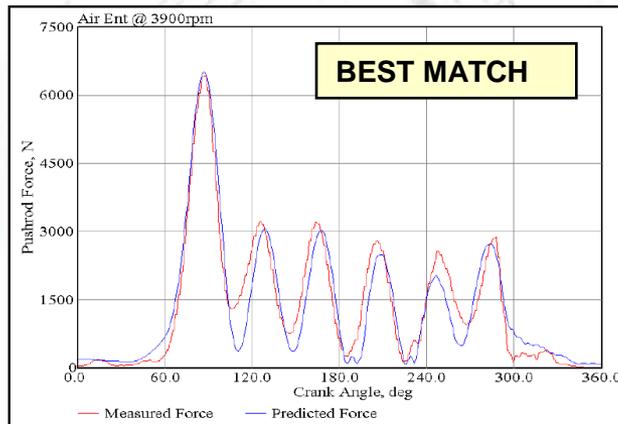
- 0% Entrained Air



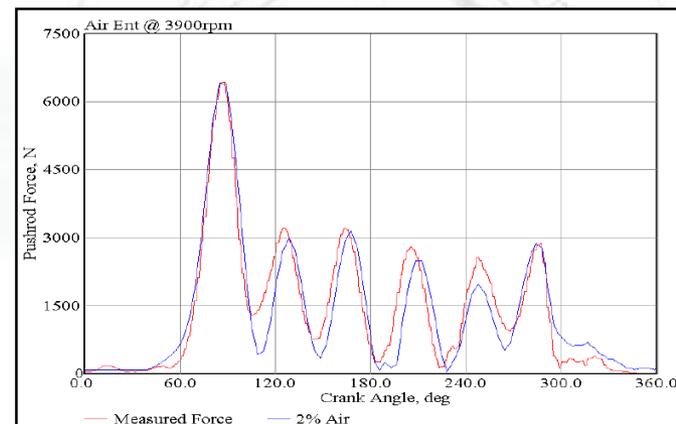
- 1% Air Entrained



- 1.75% Air Entrained



- 2% Air Entrained



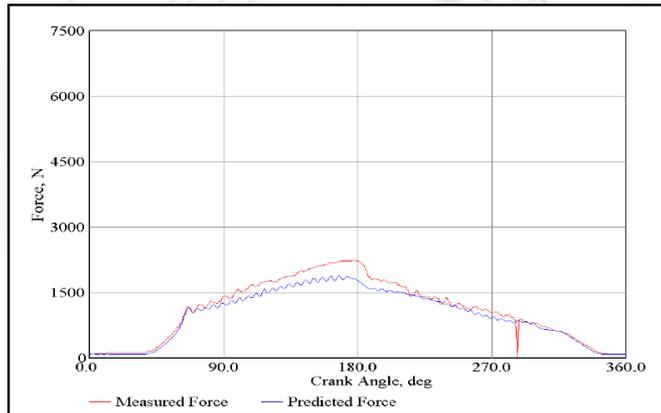
本文来自: www.idaj.cn

谢绝未经IDAJ许可的转载!

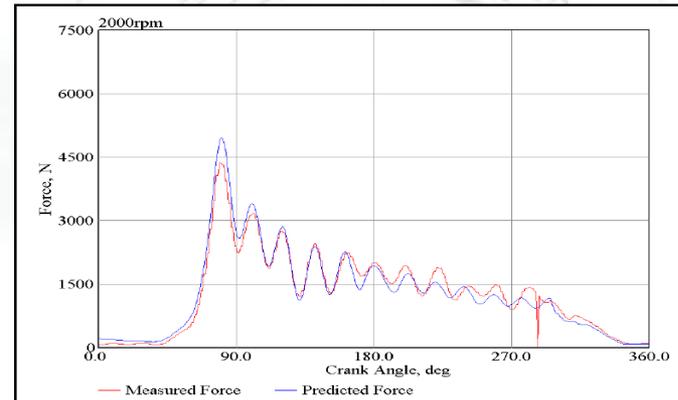
技术咨询: support@idaj.cn

配气机构及液力间隙调节器挺杆力

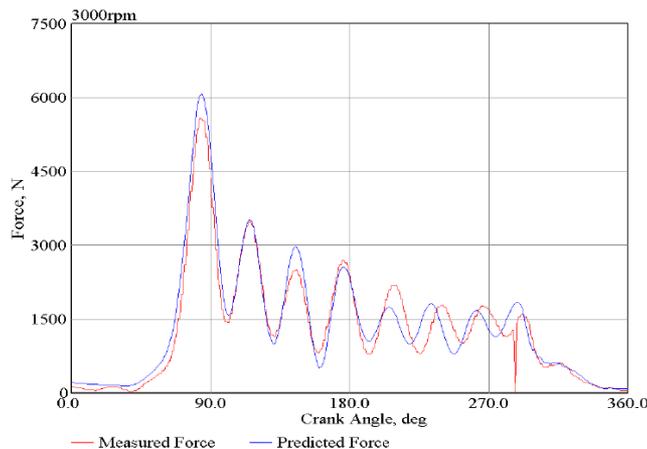
- Idle



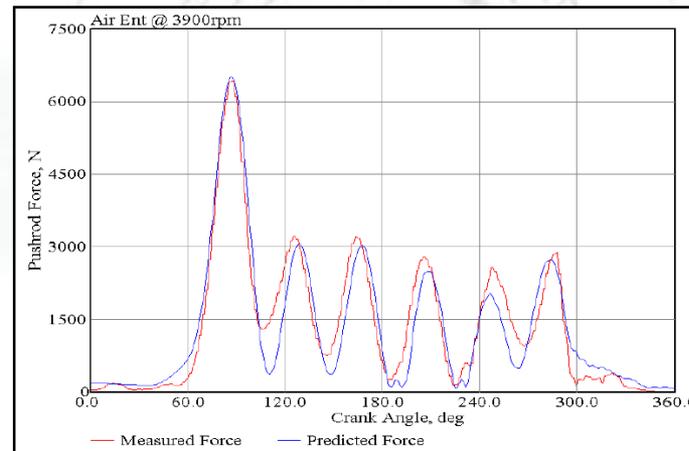
- 2000rpm WOT



- 3000rpm WOT



- 3900rpm WOT





感谢您的关注！