universal mechanism

多体系统动力学仿真

UM 软件强基训练系列教程 (04)

四川同算科技有限公司

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《UM软件强基训练系列教程》面向具有 UM 软件使用基础的用户,作为对《UM 软件入门系列教程》和《UM 培训教程》的补充和强化,教程中使用的部分例子取自 UM 软件自带的模型。

希望读者重视基础,勤加练习,多多思考,相信通过每一次练习都能有所收获。

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1 UM Input 建模过程

1.1 定义参数符号

开始建模之前,先在左下角参数列表处添加6个长度参数和1个角度参数:

rl=1

a=rl*cos(pi/6)

b=*r1*sin(pi/6)*

*r2=2*a*

```
xl=sin(angle*dtor)
```

angle=7.5(°)

```
zl=cos(angle*dtor)
```

注: r2 须在 a 之后, x1 和 z1 须在 angle 之后。

Whole list

| Name | Expression | Value | Comment |
|-------|-----------------|------------|---------|
| r1 | 1 | | m |
| a | r 1*cos(pi/6) | 0.8660254 | m |
| b | r 1*sin(pi/6) | 0.5 | m |
| r2 | 2*a | 1.7320508 | m |
| angle | 7.5 | | ۰ |
| x1 | sin(angle*dtor) | 0.13052619 | m |
| z1 | cos(angle*dtor) | 0.99144486 | m |





1.2 建立几何模型

Rotor: 由 1 个 Profiled (红色)和 3 个 Cone (颜色分别为: 橙色、绿色、紫色) 组成。

Profiled Parameters:

Profile: Type of section: Curve 2D; Scale X=1, Scale Y=1; 勾选 Close, 点击 Description 右侧 图标, 创建曲线: 通过 4 个点, 坐 标分别为: (-a, -b)、(0, r1)、(a, -b)、(-a, -b), 建立一个正三角形。 点击右键, 选择 Add new curve, 添加第二条曲线: 通过点 (0, 0) 和 (0, 0.05) 定义一个半径为 0.05(m)的圆。

Axis curve: Type of curve: Straight line, Length=0.2(m).

| Name: Rotor 🖋 🕂 🖬 🛅 Comments/Text attribute C | |
|--|---|
| Description GO position Profiled | |
| Type: 🖕 Profiled 🗸 🕂 🖬 | Description GO position Profiled |
| Parameters Colors GE position Material | Type: 🌆 Profiled 🧹 🕂 🖬 |
| Type of section O Circle O Spline 3D O Curve 2D Expression | Parameters Colors GE position Material Profile Axis curve Type of curve: Straight line |
| Scale X: 1.000 1 Scale Y: 1.000 1 | Length 0.200 |
| Number of points: 40 Close Description: Curves: 2 | Number of points: 10 Reverse normal on ends Do not rotate about the tangent |







Description GO position Profiled Type: 🍋 Profiled 🗸 🕂 🚺 Comments/Text attribute C Parameters Colors GE position Material Translation С X: С y: С Z: Rotation С Y 🗸 90 С \sim C \sim Shift after rotation С x: С y: C Z:





Conel Parameters: R2=R1=r2, h=0.2(m), Angles 定义域: [30, 90], Closing

闭合方式选择 Segment。

GE position: Translation: x=-b, y=-a, $z=-0.1(m)_{\circ}$

| | GO position |
|--|--|
| | Profiled Cone |
| | Type: A Cong + 🖬 🛱 |
| Description GO position | |
| Profiled Cone | Comments/Text attribute C |
| - | |
| Type: 🛕 Cone 🗸 🛨 🛄 | Parameters Colors GE position Material |
| Comments/Text attribute C | Translation |
| | |
| Parameters Colors GE position Material | y: _a |
| Radius (R2): r2 | z:0.1 |
| Radius (R1): r2 | Rotation |
| Height (b): 0.2 | |
| Number of points | |
| Bottom circle: 20 | |
| Generatrix: 2 | Shift after rotation |
| | x: |
| Angles: 30.00 2 90.00 2 | y: |
| Closing: Segment ~ | Z: |
| | |
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| () | |





Cone2 Parameters: 复制 Cone1, 保持 Parameters 不变。

GE position: Translation: x=-b, y=a, z=-0.1(m), Rotation: 绕 Z 轴旋转-120(°)。

| Description GO position Profiled Cone Cone | Description GO position Profiled Cone Cone Type: Cone Comments/Text attribute C |
|---|--|
| Type: 🔥 Cone 🗸 🕂 🖬 | |
| Comments/Text attribute C | Parameters Colors GE position Material |
| connerta rexe da lodic e | x: -b |
| Provention in the later of the later | v: a C |
| Parameters Colors GE position Material | 7: -0.1 |
| Radius (R2): r2 | 2, 0,1 |
| Radius (R1): r2 | z v -120 |
| Height (h): 0.2 | |
| Number of points | |
| Bottom circle: 20 | |
| Generatrix: 2 | Shift after rotation |
| Angles: 30.00 1 90.00 | x: |
| Closing: | y: |
| closing. | Z: |
| | |





Cone3 Parameters: 复制 Cone1, 保持 Parameters 不变。

GE position: Translation: x=r1, y=0, z=-0.1(m), Rotation: 绕 Z 轴旋转 120(°)。

| | Description GO position |
|--|---|
| | Profiled Cone Cone Cone |
| Description GO position Profiled Cone Cone Type: A Grass A Grass | Type: <u>A</u> Cone \checkmark 🕂 💽 🗑 Comments/Text attribute C |
| Commente /Text attribute C | Parameters Colors GE position Material |
| comments/rext attribute c | ransiation x: r1 |
| Parameters Colors CE position Material | y: 0 |
| Padius (P2), r2 | z: -0.1 |
| | Rotation |
| Radius (R1): 12 | Z ~ 120 C |
| Number of points | |
| Bottom circle: 20 | |
| Generatrix: 2 | Shift after rotation |
| | x:C |
| Angles: 30.00 | y:C |
| Closing: Segment ~ | z:C |
| | |





Shaft: 由 3 个 Cone 组成,颜色分别为:紫色、蓝色、黄色。

| 1 | Name: Shaft Comments/Text at | tribute C | (+ (| |
|---|---|-----------------------------------|-------------|---|
| | Description GO p Cone Type: A Cone Comments/Text | osition e v 🕂 [attribute C | • | X |
| | Parameters Col Radius (R2): Col Radius (R1): Col Height (h): Col Number of point Bottom circle: Generatrix: Angles: 0.00 Closing: | ors GE position Mate | | |
| | | | | |





| Cone2 Parameters: 复制 Cone | e1,保持 Parameters 不变。 |
|---|--|
| GE position : Translation: $z=1$ | (m), Rotation: 绕Y轴旋转-angle(°)。 |
| | Description GO position |
| | Cone Cone |
| | |
| Description CO position | Type: 🔥 Cone 🗸 🕂 🛄 |
| | Comments/Text attribute C |
| | |
| Type: 🛕 Cone 🗸 🕂 📑 🛅 | Parameters Colors GE position Material |
| Comments/Text attribute C | Translation |
| | x: |
| Parameters Colors GE position Material | y: |
| Radius (R2): 0.05 | z: 1 |
| Radius (R1): 0.05 | Rotation |
| Height (h): 1 | |
| Number of points | Y V -angle |
| Bottom circle: 20 | |
| Generatrix: 2 | x: C |
| Angles: 0.00 | v: C |
| | 7. C |
| (none) | |
| - • • • • • • | |
| n 1 | |
| | |
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| | 7 |
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| Cone3 Parameters: 复制 Cone | 1, 保持 Parameters 不变。 |
|---|--|
| GE position : Translation: $x=-$ | x1, $z=1+z1_{\circ}$ |
| | Description GO position |
| | Cone Cone Cone |
| | |
| Description GO position | Type: 🔥 Cone 🗸 🛨 🛄 |
| Cone Cone Cone | Comments/Text attribute C |
| - [| |
| Type: 🛕 Cone 🗸 🛨 🛄 | . Parameters Colors GE position Material |
| Comments/Text attribute C | Translation |
| | x: -x1 |
| Parameters Colors GE position Material | y: |
| Radius (R2): 0.05 | z: 1+z1 |
| Radius (R1): 0.05 | Rotation |
| Height (b): 1 C | |
| Number of points | |
| Bottom circle: 20 | |
| Generatrix: 2 | Shift after rotation |
| | x: |
| | y: |
| Closing: (none) ~ | Z: |
| | |





1.3 定义刚体参数

Rotor: 选择几何 **Rotor**, 定义 Mass=30(kg), Ix= Iy=6 (kg*m²), Iz=12 (kg*m²),

质心在坐标原点。







Shaft: 选择几何 Shaft, 定义 Mass=2(kg), Ix=Iy=1 (kg*m²), Iz=Ixz=0.1 (kg*m²),

质心坐标为: (-0.065, 0, 1.496)。







1.4 描述铰

jBase0_Shaft:选择 Base0 作为铰的 1 号物体, Shaft 为 2 号物体, 类型为 Rotational。

Joint points (0, 0, 0) 和 (0, 0, 0);

Joint Vectors (0, 0, 1) 和 (0, 0, 1)。







jShaft_Rotor:选择 Shaft 作为铰的 1 号物体, Rotor 为 2 号物体, 类型为 Rotational。

Joint points (-x1, 0, 2.5) 和 (0, 0, 0);

Joint Vectors (0, 0, 1) 和 (0, 0, 1)。







1.5 创建 Sensors

先在模型树中选中刚体 **Rotor**,然后在其 Points 页面,创建 3 个标记点,坐标 分别为: (r1, 0, 0), (-b, -a, 0), (-b, a, 0)。



选中左侧模型树的第二级 Object, 在右侧的 Sensors/LSC-Sensors 页面, 点击 + 按钮, 依次选择刚体 Rotor 上的 3 个标记点。



完成建模,保存模型。

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2 UM Simulation 仿真过程

2.1 创建变量

运行 UM Simulation 程序,加载模型(最好关闭 UM Input 程序),设置动画窗口背 景颜色为黑色。

打开变量向导,从 Sensors 界面创建己有的 3 个点的 Coordinate 的矢量 V,拖入动 画窗口,即可记录 Rotor 的 3 个顶点的运动轨迹。

注意:动画窗口中的变量列表默认是隐藏的,可通过右键菜单设置其显示的位置, 双击某个变量可修改颜色和最大数据点数,本例运动轨迹皆设置为白色。

| 😨 Wizard of variables | | | | | | | |
|--|---------------------|--|-----------------|-------------------------------------|----------------|--------------------|--|
| a+b Expression | User variables | 🕪 Reactions | Coordinates | Solver variable | es 🛛 茸 All for | ces id Identifiers | |
| 🥩 Variables fo | r group of bodies | Sensors | 🔍 Joint forces | 🛕 Angular | variables | 🛃 Linear variables | |
| eluo Sensor 1 (Body: Rotor; x: i Sensor 2 (Body: Rotor; x: i | | Selected (total 3) Sensor 1, Sensor |) 2, Sensor3 | | | | |
| Sensor | r3 (Body: Rotor; x: | O Coordinate | Ov | elocity | ○ Accel | eration | |
| | | Component O X | ОY | ⊖z | 0111 | Ov | |
| | | Resolved in SC | ofbody | | | | |
| | | Base0 | | | | _ | |
| | | | | | | | |
| r:v(Sensor1,) Sensor(Sensor1,): r; Vector | | | | | | | |
| :v(Rotor.Sensor1) :v(Rotor.Sensor2) :v(Rotor.Sensor3) | | | | | | | |





创建Rotor和Shaft相对于Base0的角速度Ang.velocity的分量Z并拖入绘图窗口。

| 🕎 Wizard of variables | | | | | — × |
|---|---|---------------------|-------------------|------------------------------------|-----------------------|
| a•b Expression User variables Image: Variables for group of bodies Image: Variables f | Reactions Sensors Selected (total 2) Rotor, Shaft Type of variable Rot. vector Component X Resolved in SC of Base0 Relative to body Base0 | Coordinates | Solver vari | ables 📑 All Ilar variables 🔾 An | forces id Identifiers |
| om:z(Rotor,) Ar om:z(Rotor) om:z(Shaft) | ngular velocity of bo | dy (Rotor,) relativ | e to Base0, SC Ba | ase0, projection Z | |
| Plots | | | | | |
| Variables | | 4 6 | | 10 | Time, sec |





2.2 工况1

在仿真控制界面的 Initial conditions 页面可以查看铰坐标和系统自由度。设置 Shaft 相对 Base0 的 Z 轴转速为 3(rad/s), Rotor 相对于 Shaft 的转速为-2(rad/s)。

| Object variables | | | | XVA | | | Information | |
|------------------|-------|---------|------------------------|-------------------|--------|--|----------------------------|--|
| Solver | | | | Identifi | iers | | Initial conditions | |
| dinat | es | Cons | straints on initial co | nditions | | | | |
| | | | | | | | | |
| 2 | | • | ⊕ | =0 v=0 | ⊻ | | | |
| 2 | ‡ | @• ✓ | Coordinate | =0 v=0 Ve | locity | | Comment | |
| 2 | ‡ | @• ✓ | Coordinate 0 | =0 ν=0 Ve 3 | locity | | Comment jBase0_Shaft 1a | |

在 Solver 页面设置仿真时长为 5(s),数据步长为 0.005(s)。

| Object variables | | XVA | Info | Information | | |
|--|--|-------------------------|----------------------|-------------|--|--|
| Solver | Identifie | rs | Initial conditions | | | |
| Simulation process paramete | ers Solver options | Type of co | ordinates for bodies | PP: Options | | |
| Solver BDF ABM Park Gear 2 Park Parallel | Type of solution Null space meth Range space meth | od (NSM) ethod (RSM) |) | | | |
| Time | <u>t</u> > ~ | 5 💻 | | | | |
| Step size for animation and o | data storage 0.005 | | | | | |
| Delay to real time simulat Keep system matrix deco Computation of Jacobian | ion mposition | | | | | |





仿真结果如下图:



从动画窗口可以看出, Rotor 三个顶点的运动轨迹是重合的; 从绘图窗口可以看出, Rotor 相对于 Base0 的转速为 3-2=1(rad/s), Rotor 和 Shaft 的转速比为 3: 1。





2.3 工况2

在 Initial conditions 页面设置 Shaft 绕 Base0 的 Z 轴转速为 3(rad/s), Rotor 相对于 Shaft 的转速为-4(rad/s)。

| Object sin | nulat | 1011 | inspe | ctor | | | | | | | |
|--------------------|---------------|--------|------------------------------|------|----|--------------------|---------------|--|--|-----------------|--|
| | Obje | ect v | ariable | s | | | XVA | | | Information | |
| Solver | | | Identifiers | | | Initial conditions | | | | | |
| Coordinat | tes o | ons | straints on initial conditio | | | dition | s | | | | |
| | | \sim | | | | | | | | | |
| | 1 (| a.+ | Ð | Θ | X= | 0ν | =0 <u>V</u> | | | | |
| | ÷ | ✓ | Coordi | nate | | | Velocity | | | Comment | |
| 1.1 | | | 0 | | | | 3 | | | jBase0_Shaft 1a | |
| 1.2 | | | 0 | | | | -4 | | | jShaft_Rotor 1a | |
| | | | | | | | | | | | |
| | | | | | | | | | | | |
| Messa | ge | dx | = | 0.1 | | da= | 0.1 | | | | |
| Messa Number of | ge f d.o.f | dx= | =2 | 0.1 | | da=[| 0.1 | | | | |





仿真结果如下图:



从动画窗口可以看出, Rotor 三个顶点的运动轨迹是重合的,形状接近一个圆角矩形;从绘图窗口可以看出, Rotor 相对于 Base0 的转速为 3-4=-1(rad/s), Rotor 和 Shaft 的转速比为 3: -1。





2.4 工况3

在仿真控制界面的 Identifiers 页面设置 r1=1.5 (m),此时 Rotor 的整体尺寸会发生 改变(如果动画窗口未刷新,只需关闭仿真控制界面,然后点击 File-Close 关闭模型,再点击 File-Reopen 重新打开模型即可)。

| Solver ist of identifiers | | XVA | | Information | |
|------------------------------|---|--|----------------------------------|---|--|
| ist of identifiers | Solver | | | Initial conditions | |
| | Identifier control | | | | |
| 🕞 💾 🗆 🔊 | | | | | |
| Whole list | - | | | | |
| whole list | F . | | - | | |
| Name | Expression | value | Comme | IC | |
| - | 1.5 | 1 2000291 | m | | |
| a h | r1*sin(pi/6) | 0.75 | | | |
| r2 | 2*a | 2 5980762 | m | | |
| angle | 7.5 | 2.000702 | 0 | | |
| x1 | sin(angle*dtor) | 0.13052619 | m | | |
| 71 | cos(angle*dtor) | 0 99144486 | m | | |
| | | | | | |
| Integratio | - | Magaza | | Class | |
| Integratio | n | Message | | Close | |
| Integratio | n UM - Simula | Message tion - c:\use | •rs\861! | Close 52\deskt | |
| Integratio Integratio | n UM - Simula le <u>A</u> nalysis | Message tion - c:\use <u>S</u> canning | ors\861! Tools | Close 52\deskt <u>W</u> indo\ | |
| Integratio Ei | n UM - Simula le <u>A</u> nalysis Open | Message tion - c:\use <u>S</u> canning | rs\861! <u>T</u> ools | Close 52\deskt <u>W</u> indo\ F3 | |
| Integratio | n UM - Simula le <u>A</u> nalysis Open | Message tion - c:\use <u>S</u> canning | rs\861! <u>T</u> ools | Close 52\deskt <u>W</u> indov F3 | |
| Integratio Ei | n UM - Simula le <u>A</u> nalysis Open Reopen | _{Message} tion - c:\use <u>S</u> canning | ers\861! Tools | Close 52\deskt Windov F3 > | |
| Integratio | n UM - Simula le <u>A</u> nalysis Open Reopen Close | _{Message} tion - c:\use <u>S</u> canning | rs\861! <u>T</u> ools Shif | Close 52\deskt Windov F3 > t+F4 | |
| Integratio Ei | n UM - Simula le <u>A</u> nalysis Open Reopen Close Load cont | Message tion - c:\use <u>S</u> canning figuration | rs\861! Tools Shif | Close 52\deskt <u>W</u> indov F3 > t+F4 > | |





仿真结果如下图:

| Animation window | |
|---|--|
| Vectors / Trajectories | |
| r:v(Rotor.Sensor1) - Sensor(Rotor.Sensor1): r; Vector r:v(Rotor.Sensor2) - Sensor(Rotor.Sensor2): r; Vector r:v(Rotor.Sensor3) - Sensor(Rotor.Sensor3): r; Vector | |
| iai < < < < < < < < < < < < < < < < < | |
| | |

本例中我们通过参数化的 Sensors 来创建仿真变量,并与几何图形尺寸关联,一旦 模型的尺寸发生变化,输出变量也相应随之变化,无需重新定义。

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