Universal joint

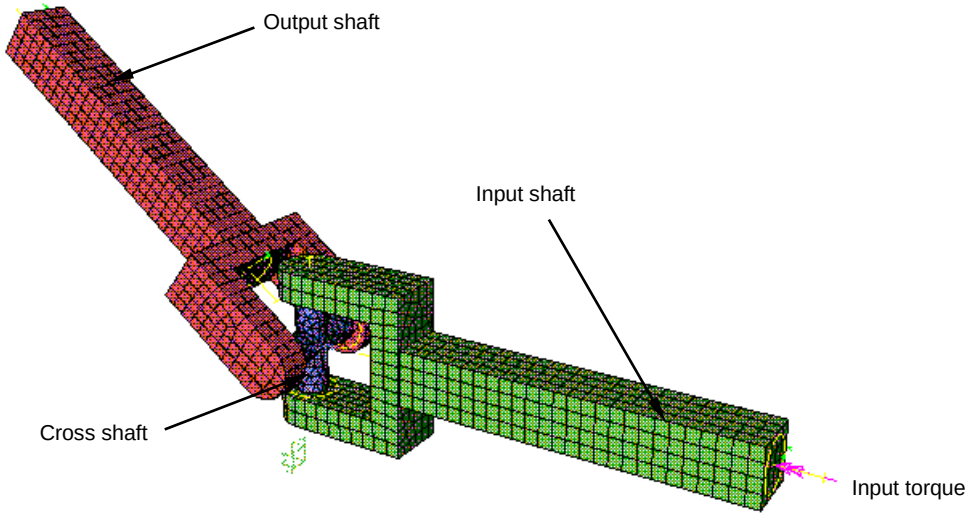
Model description

A universal joint is simulated in Fedem. The computer model consists of six links,

- INPUT SHAFT
- OUTPUT SHAFT
- DRIVESHAFT
- CROSS MEMBER 1
- CROSS MEMBER 2

Revolute joints are applied between the links. Two revolute joints are also applied between the two shafts and ground. The angle between the input and the output shaft is 20°.

The shafts will vibrate in a universal joint due to the cardan failure. The cardan effect is the rotation angle displacement between the shafts and is added because of the angles between the shaft centres. This example illustrates that Fedem calculates the behaviour of a universal joint correctly and the cardan failure is identified.



1 *Computer model of the universal joint*

Note: The use of revolute joints in universal joint modeling is unique for FEDEM. No other MBS simulation system can model a “over constrained” system like this.

Mechanism Model

UNIVERSAL_JOINT.FMM—INITIAL MODEL
UNIVERSAL_JOINT_FINAL.FMM—FINAL MODEL

Links

2 AXLE.FLM SHAFTS: SHELL ELEMENTS.
1 CROSS.FLM CROSS SHAFT: SHELL ELEMENTS.

Joints

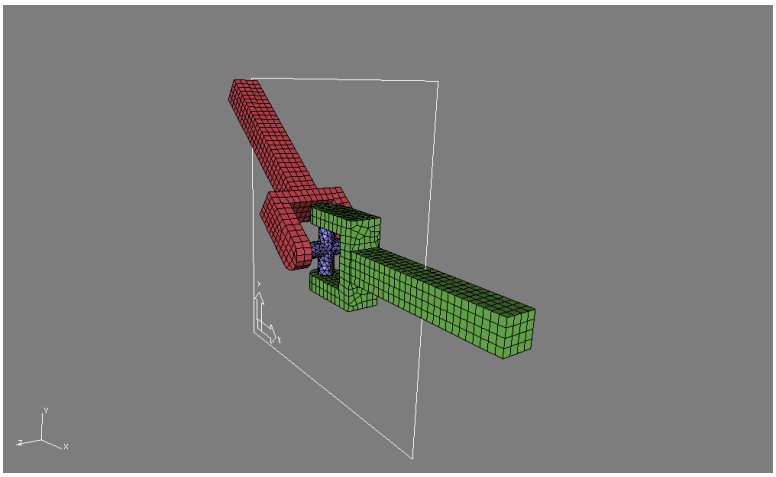
8 REVOLUTE JOINTS.

Loads

AN INPUT TORQUE APPLIED ON THE INPUT SHAFT EQUAL -5 NM.

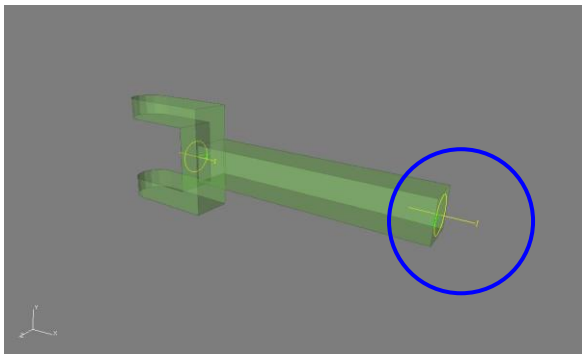
LOADS AND BOUNDARY CONDITIONS

Open  the file UNIVERSAL_JOINT1.fmm

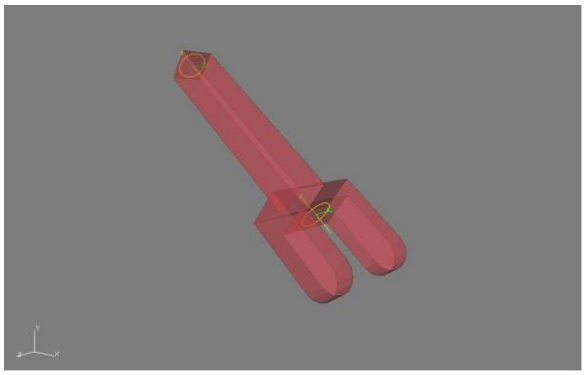


APPLY THE REVOLUTE  **JOINTS**

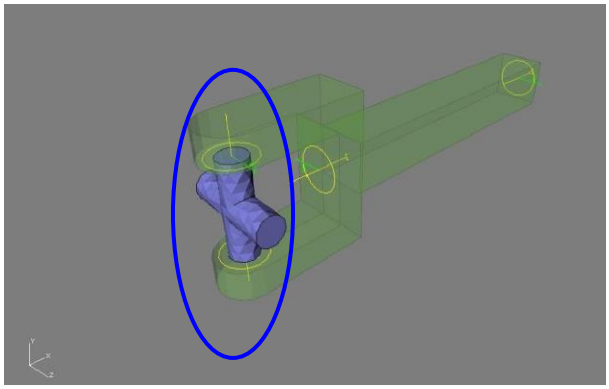
1. ATTACH  TWO REVOLUTE JOINTS TO INPUT SHAFT AND THE EARTH
2. ADD DAMPING OF 5 N.sec/m IN THE JOINT PROPERITES COLOUMN



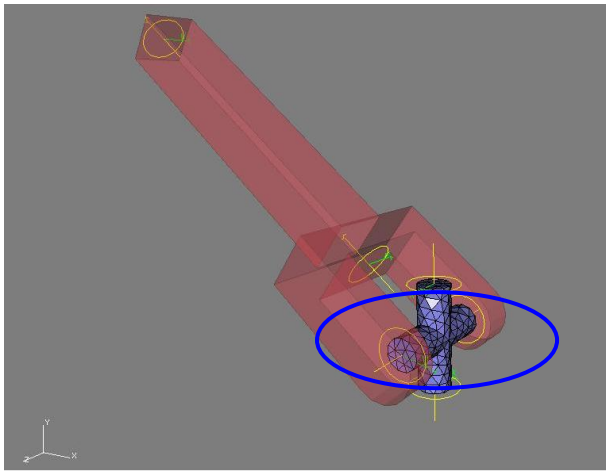
3. ATTACH TWO REVOLUTE JOINT TO OUTPUTSHAFT AND THE EARTH



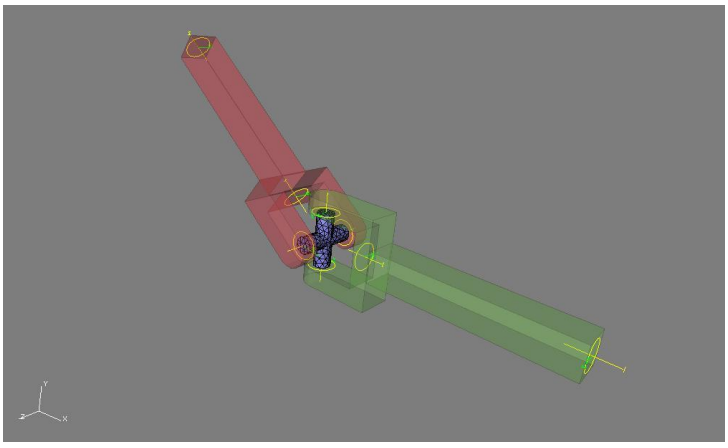
4. ATTACH TWO REVOLUTE JOINTS CONNECTING I/P SHAFT AND THE CROSS



5. ATTACH TWO REVOLUTE JOINTS CONNECTING O/P SHAFT AND THE CROSS MEMBER



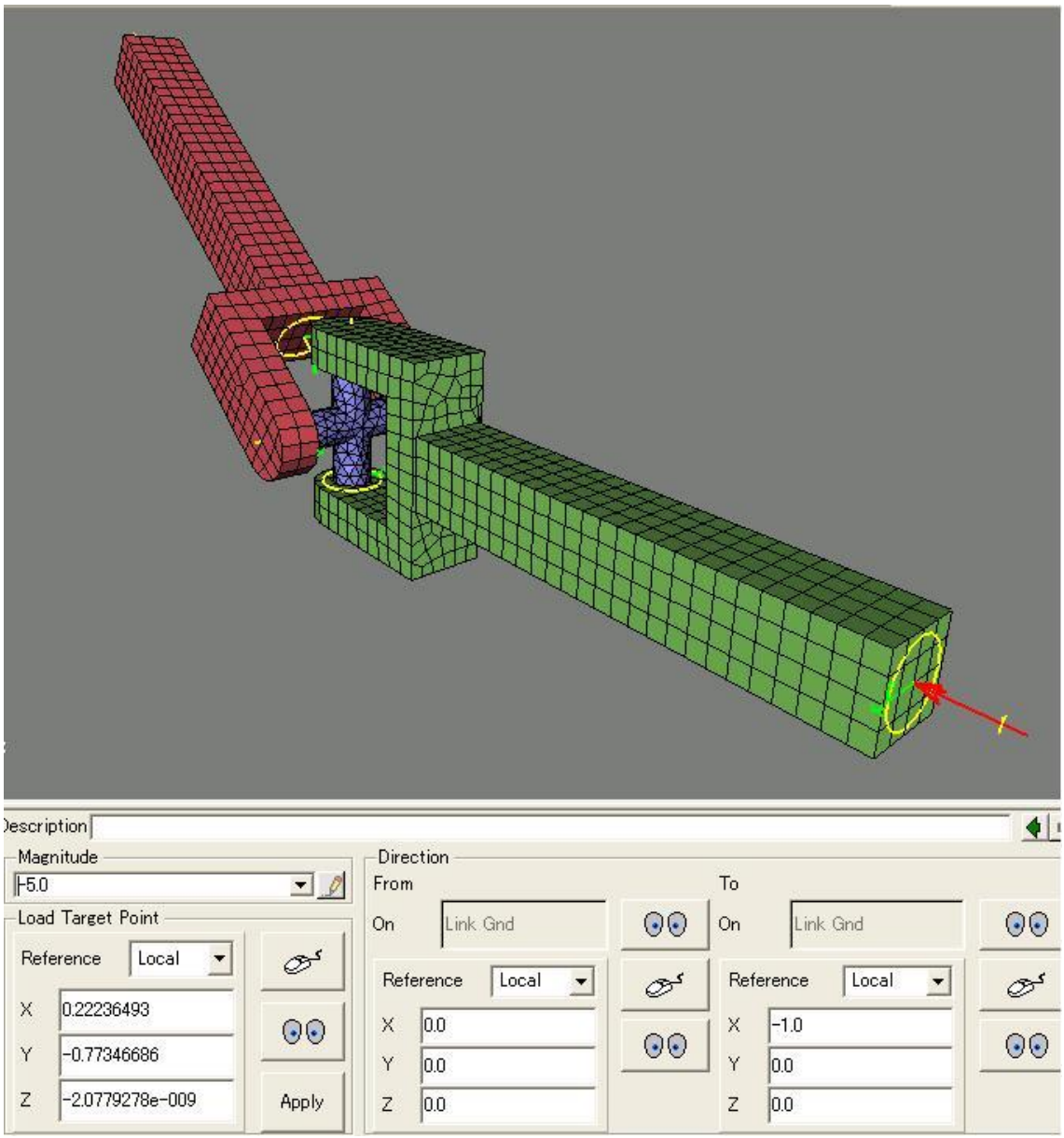
THE FINAL ASSEMBLY LOOKS LIKE



LOADS

APPLY THE INPUT TORQUE REVOLUTE JOINT IN THE TORQUE

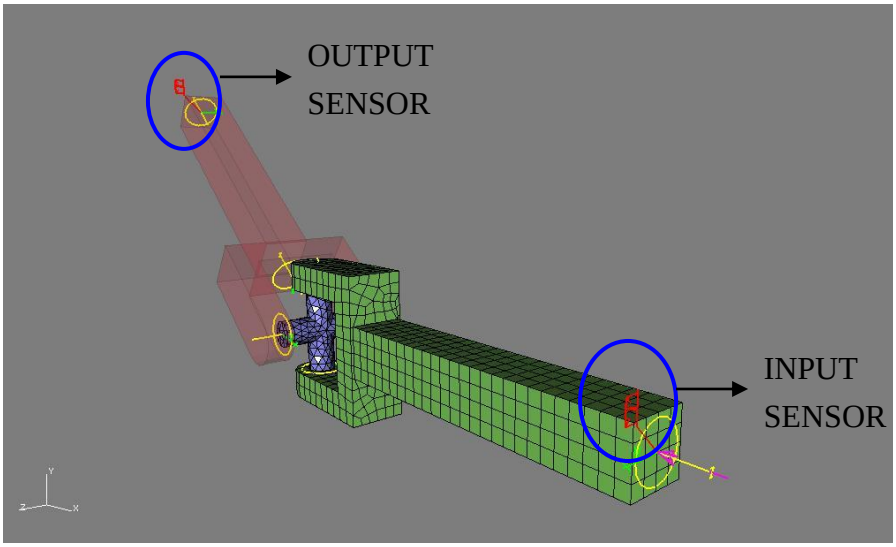
TO THE SLAVE TRIAD OF THE INPUT SHAFT AND ADD -5Nm



POSITION THE APPLIED TORQUE REFERENCE DIRECTION ALONG THE X-AXIS
COORDINATES (0,0,0) AND (-1,0,0)

SENSOR

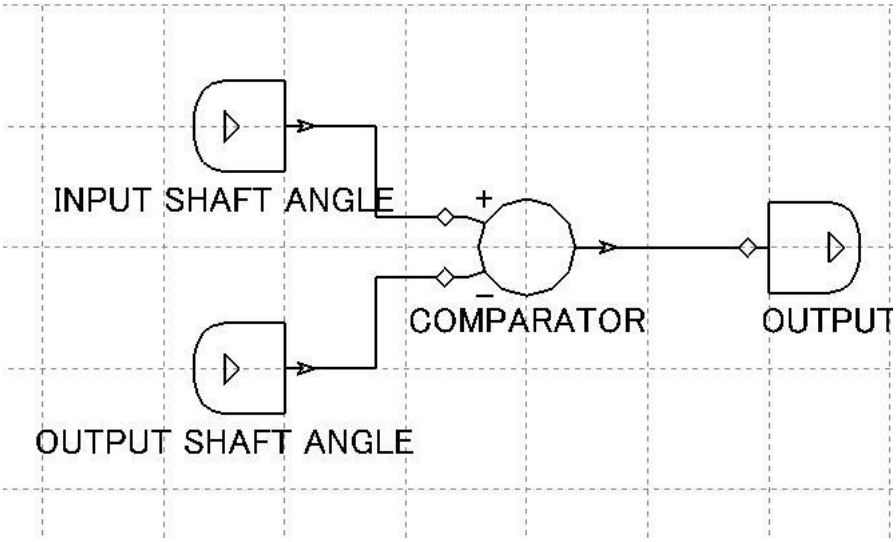
ATTACH A SENSOR TO THE INPUT AND OUT PUT SHAFT REVOLUTE JOINTS WHICH MEASURES THE INPUT AND OUT PUT ROTATION ANGLES



CONTROL SYSTEMS

TO MEAURE THE CARDAN EFFECT CREATE A CONTROL SYSTEM WITH

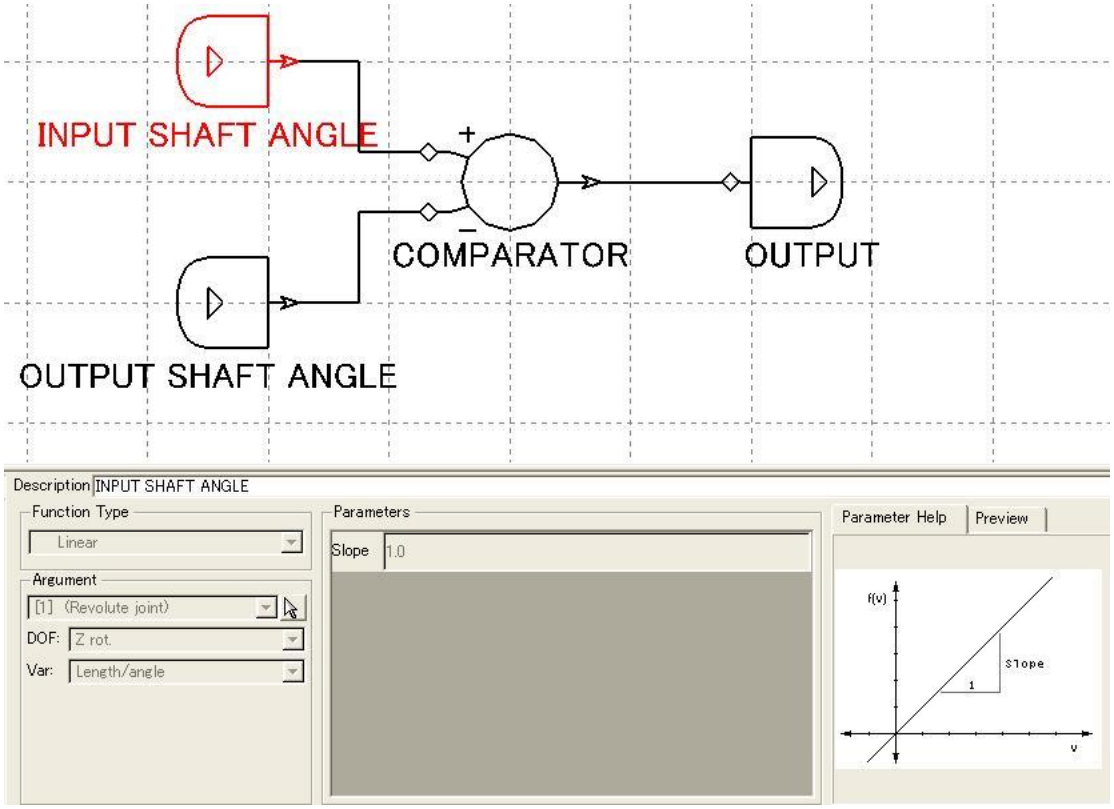
- TWO INPUTS --I/P SHAFT ANGLE AND O/P SHAFT ANGLE
- COMPARATOR—WHICH MEASURES THE DIFFERENCE
- OUTPUT



DEFINING THE INPUT SHAFT ANGLE CONTROL ELEMENT LINK TO MEASURE THE INPUT SHAFT ROTATIONAL ANGLE

CLICK ON THE INPUT SHAFT ANGLE AND IN THE BOTTOM INSERT

- FUNCTION TYPE → LINEAR
- ARGUMENT → I/P REVOLUTE JOINT
- DOF → Z ROT
- VARIABLE → LENGTH/ANGLE

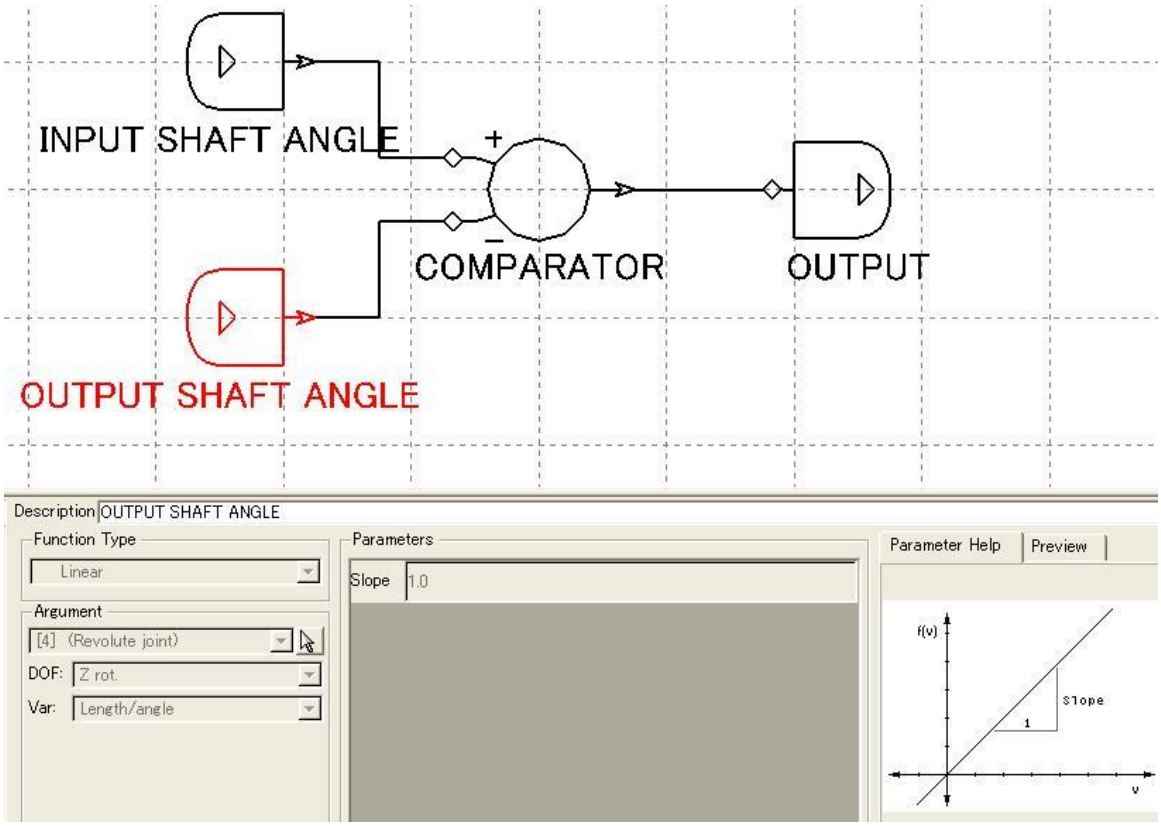


THIS DEFINES THAT THE INPUT SHAFT ANGLE CONTOL ELEMENT GIVES THE ROTATIONAL ANGLE CHANGE IN THE INPUT SHAFT

DEFINING THE OUTPUT SHAFT ANGLE CONTROL LINK TO MEASURE THE INPUT SHAFT ANGLE

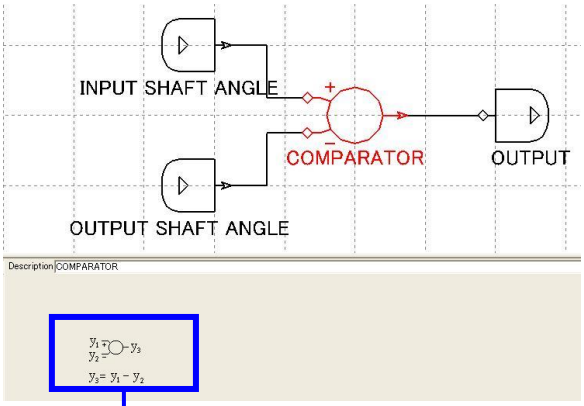
CLICK ON THE OUTPUT SHAFT ANGLE AND IN THE BOTTOM INSERT

- FUNCTION TYPE → LINEAR
- ARGUMENT → O/P REVOLUTE JOINT
- DOF → Z ROT
- VARIABLE → LENGTH/ANGLE



THIS DEFINES THAT THE OUTPUT SHAFT ANGLE CONTOL ELEMENT GIVES THE ROTATIONAL ANGLE CHANGE IN THE OUTPUT SHAFT

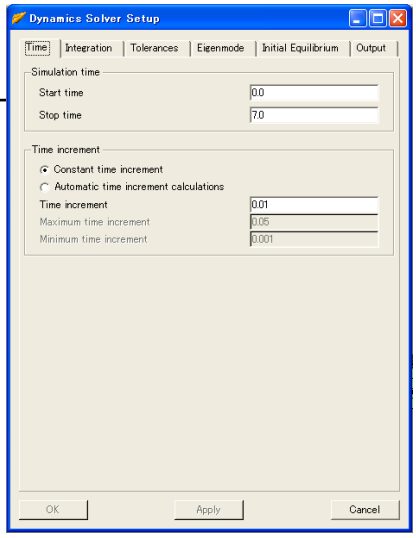
COMPARATOR



THE COMPARATOR MEASURES THE DIFFERENCE IN THE ROTATIONAL ANGLE CHANGE AND GIVES THE OUTPUT VALUE WHICH IS THE CARDAN FAILURE

SOLVING

DYNAMIC SOLVER SETUP



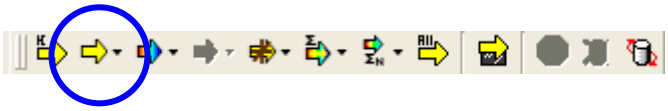
SET

THE START TIME =0.0

STOP TIME=7.0

TIME INCREMENTS=0.01

RUN THE DYNAMIC SOLVER



Results and discussion

The input shaft is driven by an input torque giving the input shaft a constant velocity. The input velocity is almost constant, while the output velocity is oscillating due to the cardan effect. The graph in Figure **Error! No text of specified style in document.**-2 shows the angle velocities of the shafts.

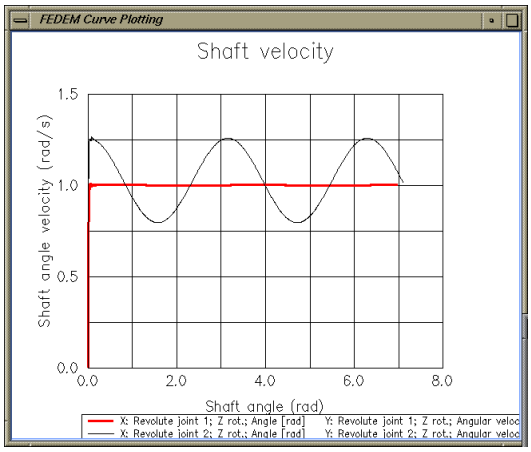


Figure Error! No text of specified style in document.**-2 Velocity of the shafts**

A control system is created in order to enable a curve plot of the difference of the angle between the input shaft and the output shaft. The difference is shown in Figure **Error! No text of specified style in document.**-3, and is called cardan failure. From Figure **Error! No text of specified style in document.**-3 the angle difference is found to be 0.114rad or 6.53°.

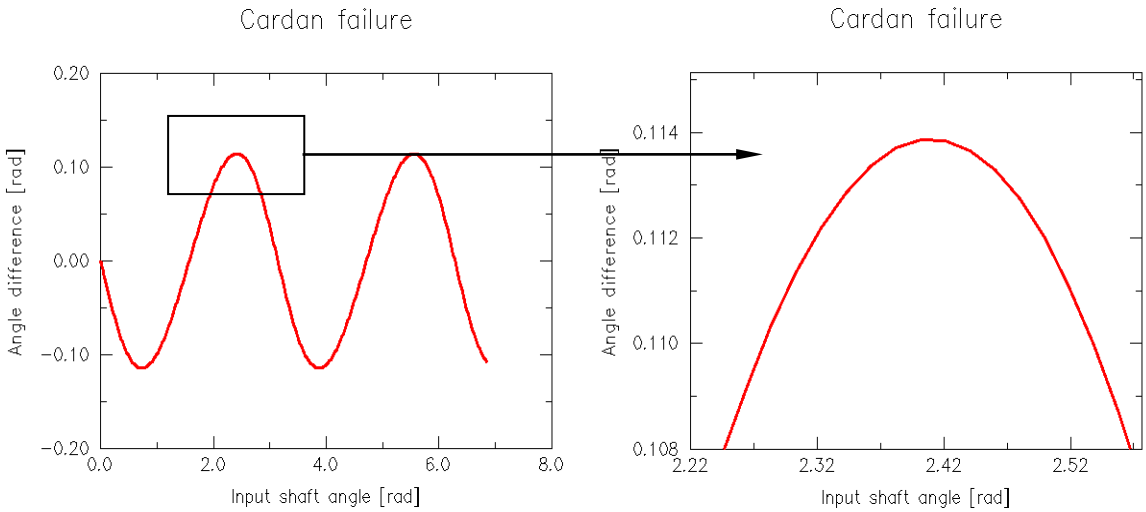


Figure Error! No text of specified style in document.**-3.** ***Cardan failure.***

Analytical calculations:

The velocity curve can be described by this geometric relationship:

$$\omega_2 = \frac{cos\beta}{1 - sin^2\beta \cdot sin^2\alpha_1} \cdot \omega_1 \left[rad/s \right]$$

where

ω_1 = Angle velocity input shaft

ω_2 = Angle velocity output shaft

α = Rotation angle input shaft

β = Angle between the shaft centers

This is the theoretical formula for the plot viewed in figure 6.7.

Chosen parameters (same as in Fedem):

$\omega_1 = 1$ rad/s

$\beta = 37.3°$

$\alpha = 90°$	or 1.57 rad	$\Rightarrow$	ω_{2max}	≈ 1.26	rad/s	
$\alpha = 0°$	or 0 rad	$\Rightarrow$	ω_{2min}	≈ 0.8	rad/s	

which is identical with the maximum and minimum values shown in Figure **Error! No text of specified style in document.**-2

The angle difference can be calculated theoretically. The angel function is:

$$\tan\alpha_2 = \frac{\tan\alpha_1}{\cos\beta}$$

where

α_1 = Rotation angle input shaft

α_2 = Rotation angle output shaft

β = Angle between the shafts

$\beta = 37.3°$

Angle difference = α_1 - α_2. Figure Error! **No text of specified style in document.-4** shows a theoretical plot of the cardan failure.

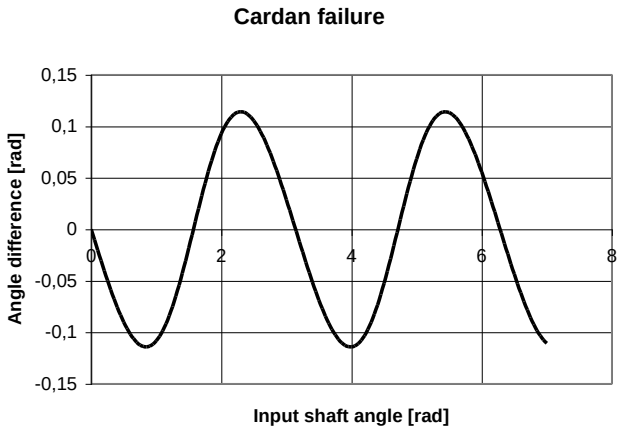


Figure Error! No text of specified style in document.**-4.** *Theoretical calculations of the cardan failure*

This maximum angle difference from the theoretical plot is ±0.114rad, which is the same as the plot from FEDEM shows. This also shows that Fedem calculate the behaviour of the universal joint correctly.

Table Error! No text of specified style in document.**-1** *Analytical and simulated cardan failure*

Pos. [rad] (Fedem)	Pos. [rad] (Calculated)	Error In %
0.114	0.114	0.0

Run times

The following run times were obtained for the cardan mechanism on a low end SGI and a high end HP:

Computer		Simulation time
Name	CPU / Memory / Disk /graphics card	[hours : min : sec]
SGI O2 Modeller	180 MHz R5000 / 128Mb / 4Gb / CRM	00 : 00 : 29
HP J2240 Visualize	236 MHz PA8000 / 2Gb / 18 Gb / fx4	00 : 00 : 14

The total number of iterations was 3500