Simulation tool to evaluate engagement performance of Synchronizer systems in post synchronization phases

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Agenda

1. Synchronizer Modeling
2. Post synchronization phases
3. AMESim Model
4. Simulation results

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Torque Interrupt shift in EV mode

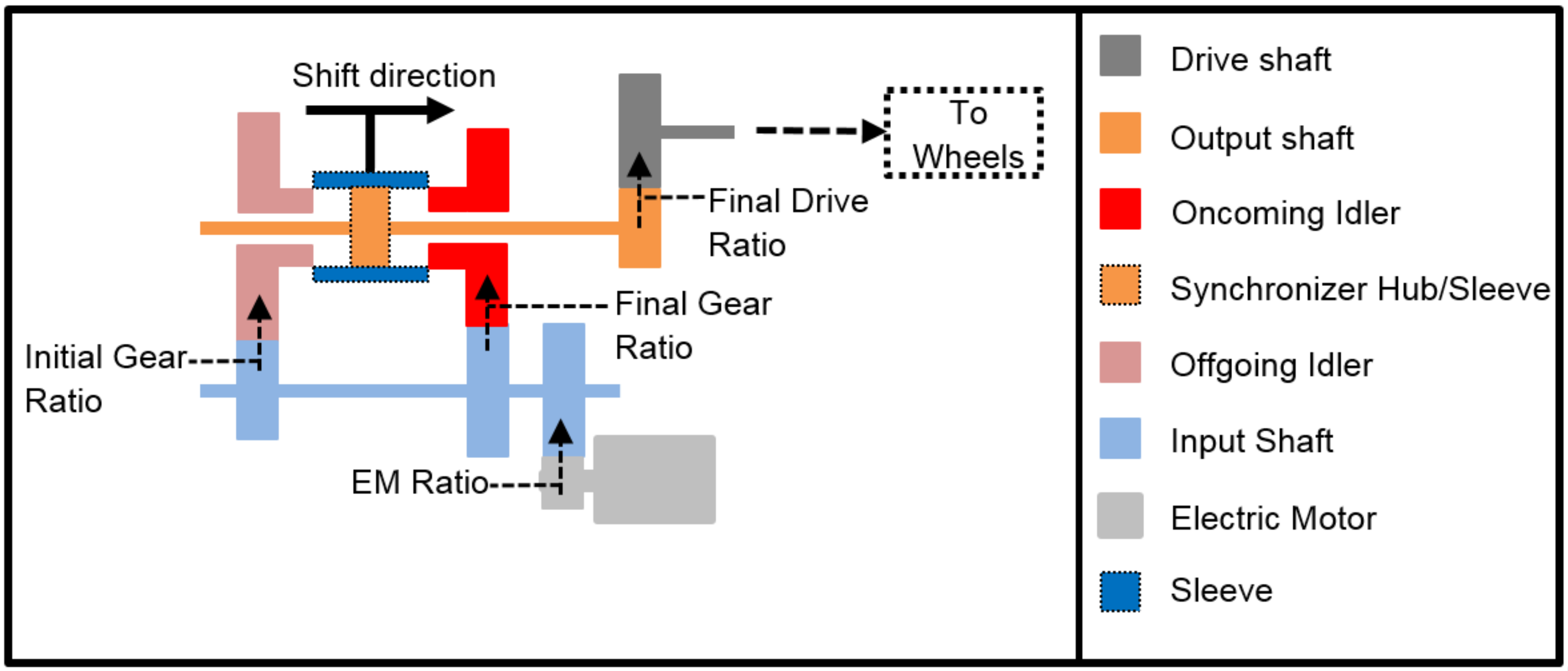
Phases in a Torque Interrupt Shift

1. Torque ramp down
2. Sleeve to Neutral
3. Speed Synchronization
4. Sleeve to Gear engagement
5. Torque Ramp up

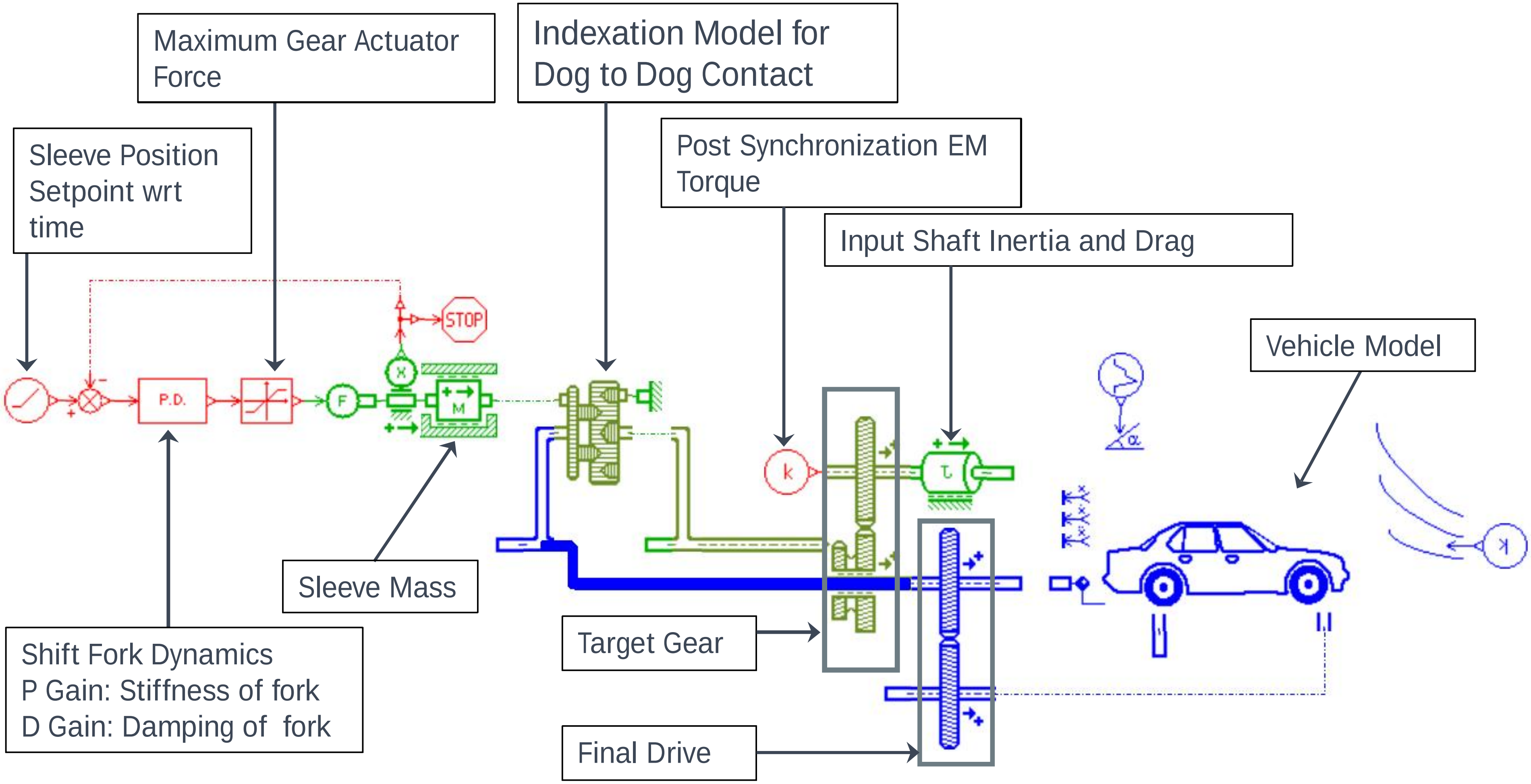
1. Takes largest percentage of shift time
2. Related to Heat Generation

Questions

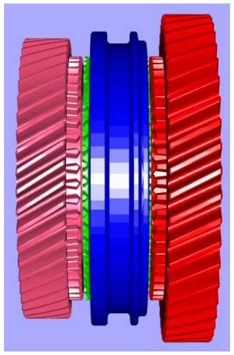
1. How long is Engagement time ?
2. What is the magnitude of Impact Forces (Frontal and Side)?

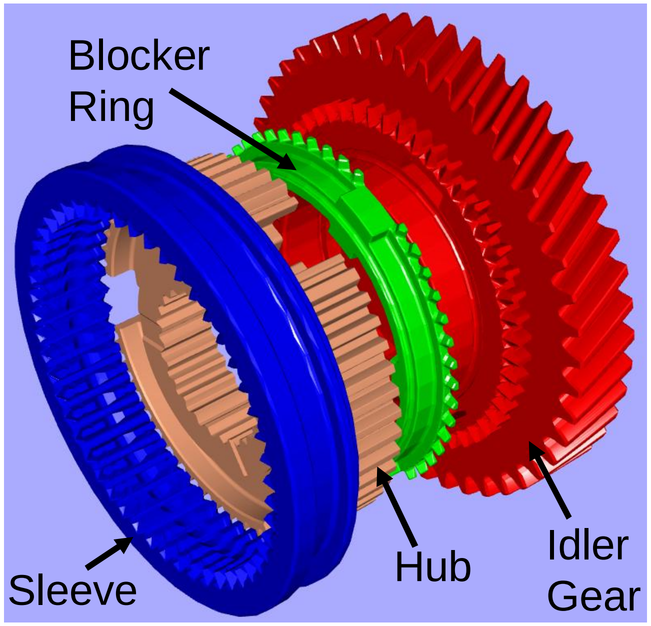


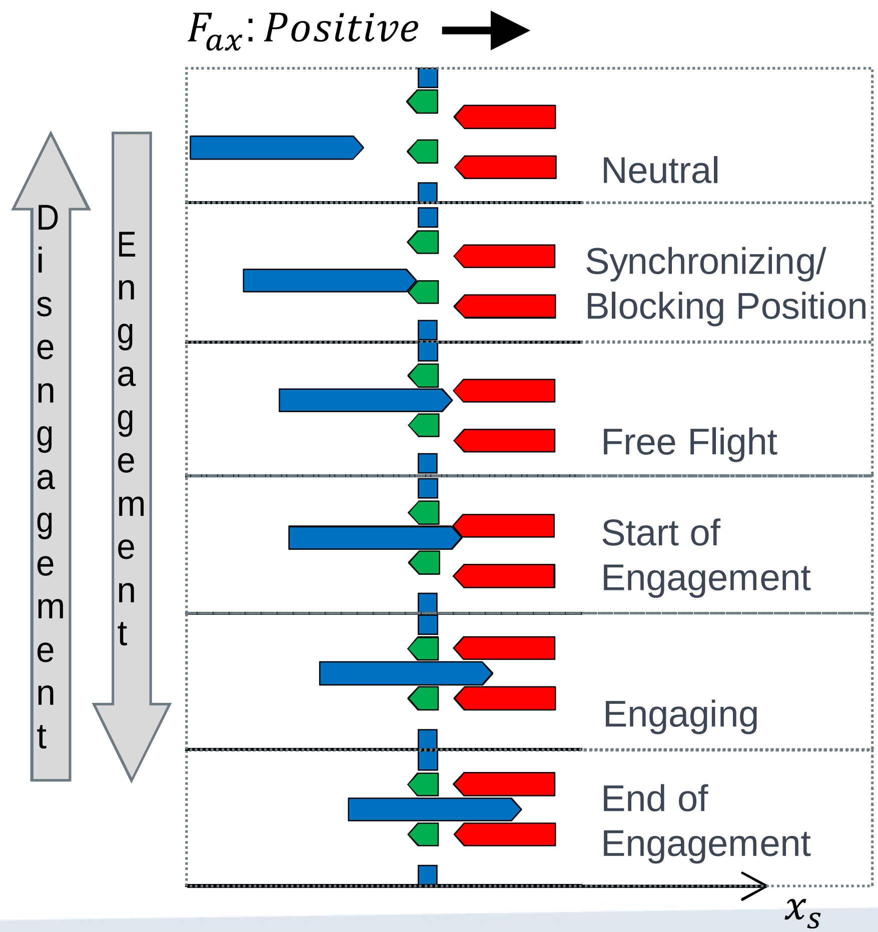
AMESim Modelling



Synchronizer Modelling

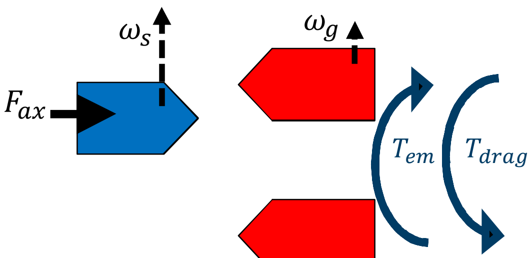






Mechanical Connections
Sleeve to Hub: Spline Coupling
Blocker Ring to Hub: Rotary bump-stops
Idler Gear to Blocker Ring: Cone Clutch

Indexation Modeling



$at\ time\ t_0 = end\ of\ speed\ synchronization$

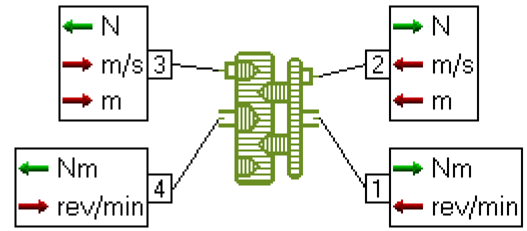
$\omega_g = \omega_s$

During Free Flight :

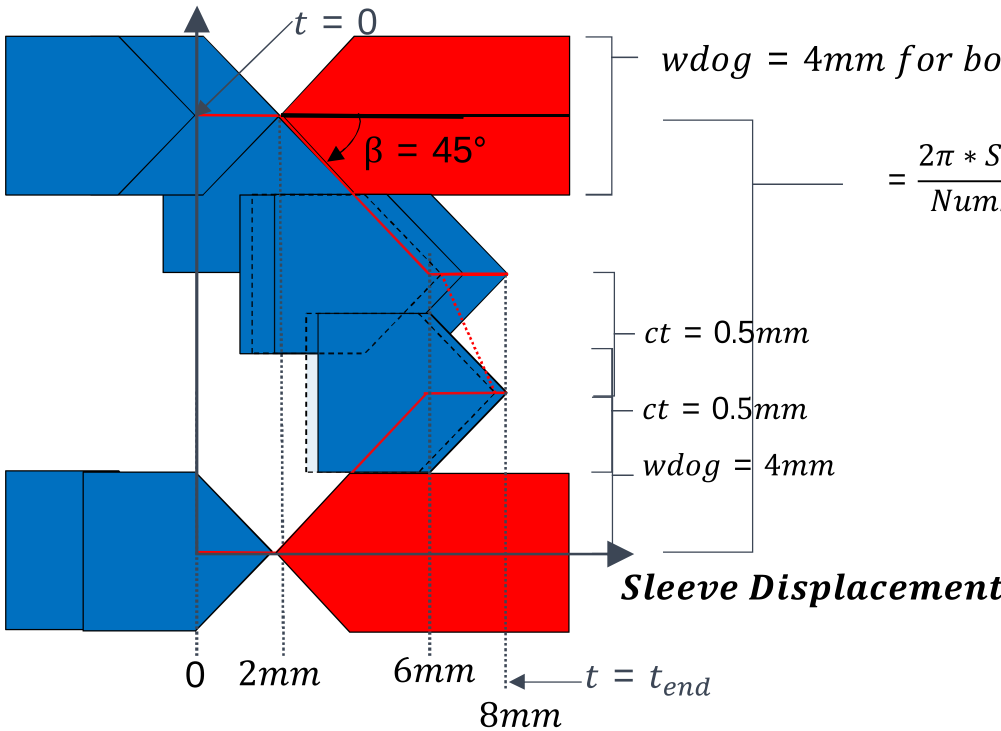
$if\ T_{em} < T_{drag}\ then\ \omega_g < \omega_s$

$if\ T_{em} > T_{drag}\ then\ \omega_g > \omega_s$

$if\ T_{em} = T_{drag}\ then\ \omega_g = \omega_s$



Relative Position between Gear and Sleeve



$wdog = 4mm\ for\ both\ Sleeve\ and\ Idler\ Gear\ dogs$

$= \frac{2\pi * Sleeve\ Radius}{Number\ of\ teeth} = 2wdog + ct = 8.5mm$

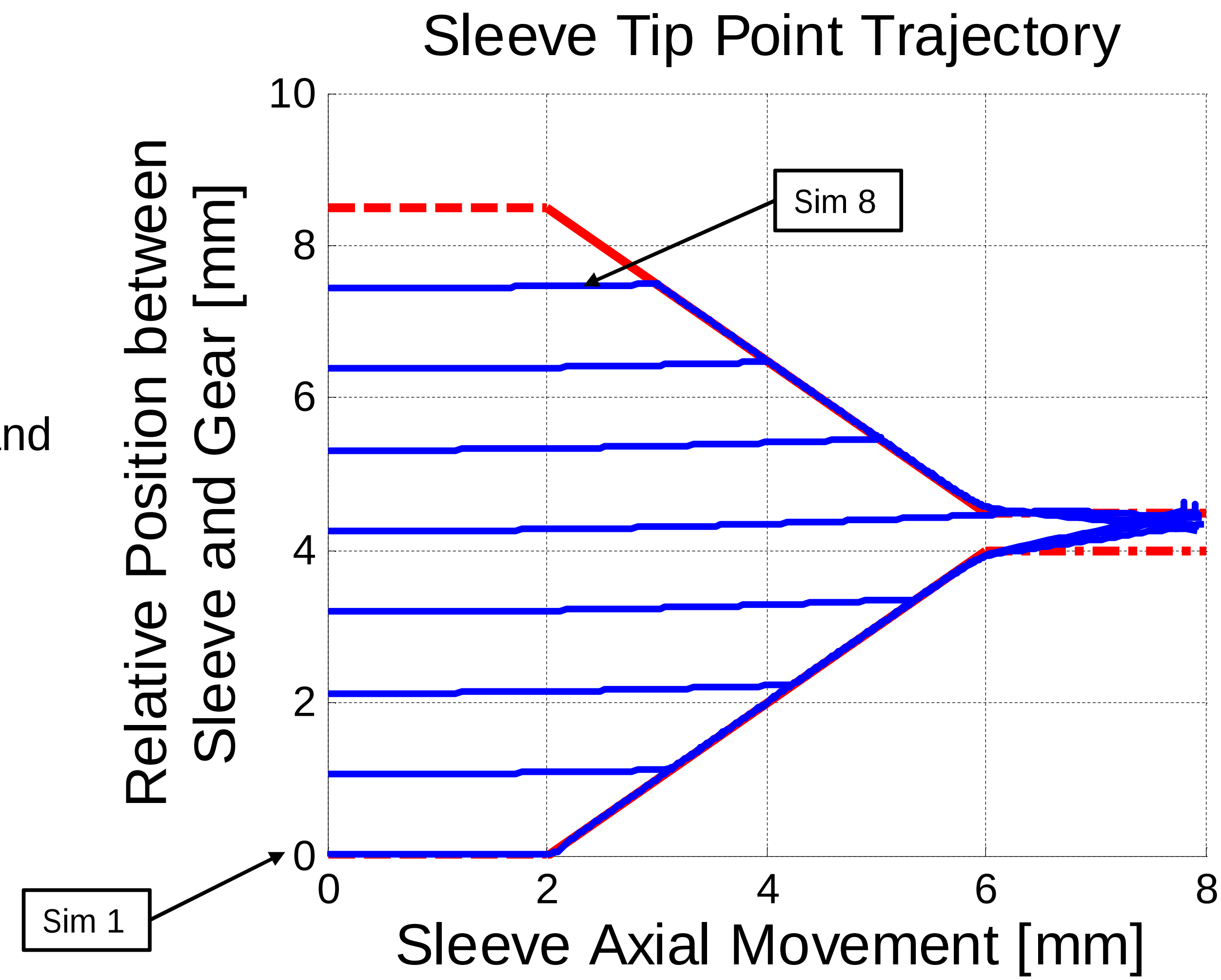
<u>*High Normal Force on Front Contact → Noise*</u>
<u>*Defined by Sleeve Displacement 2-6mm*</u>

<u>*Multiple Side Contacts*</u>
<u>*Defined between Sleeve Displacement 6-8 mm*</u>
<u>*And defined by hitting **both** Relative Position 4 and 4.5 mm*</u>

Batch Simulation

T_em=0
T_drag=15 Nm

Batch Setting:
Relative Position of sleeve and Gear
8 steps between 0 and 2*wdog+ ct

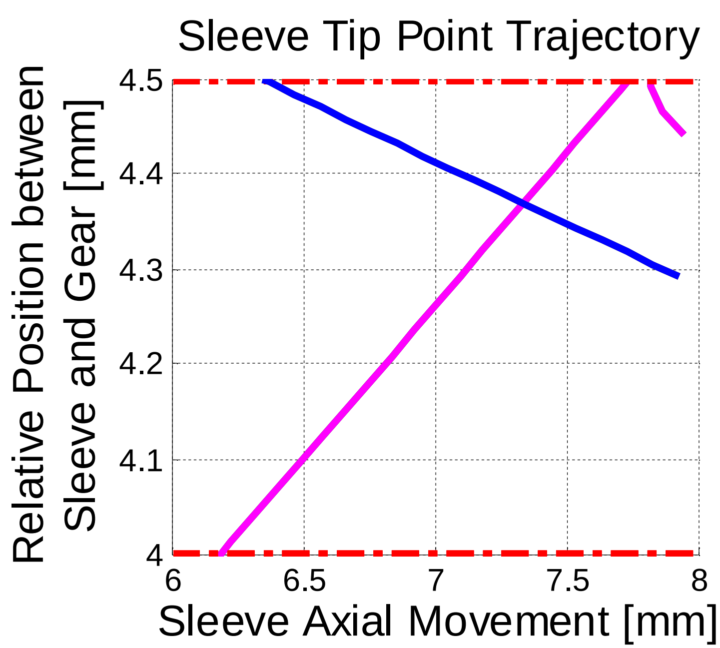


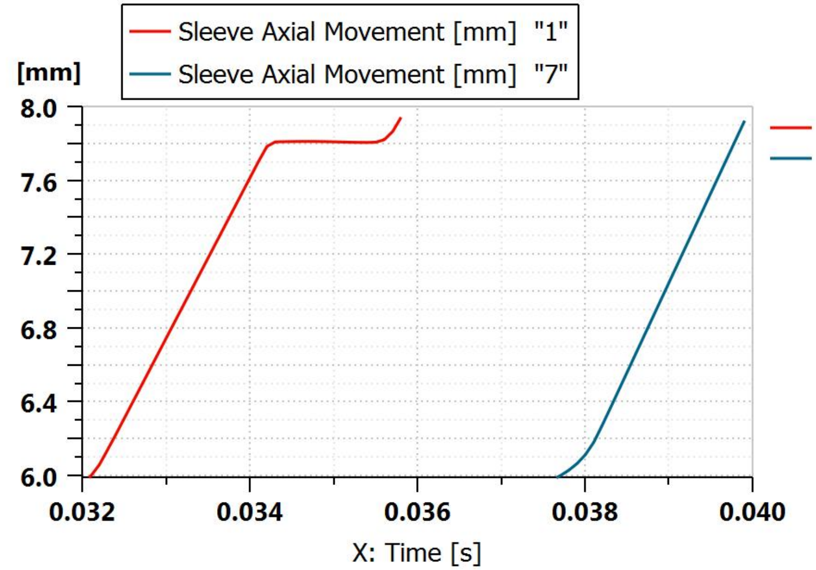
Multiple Side Contacts

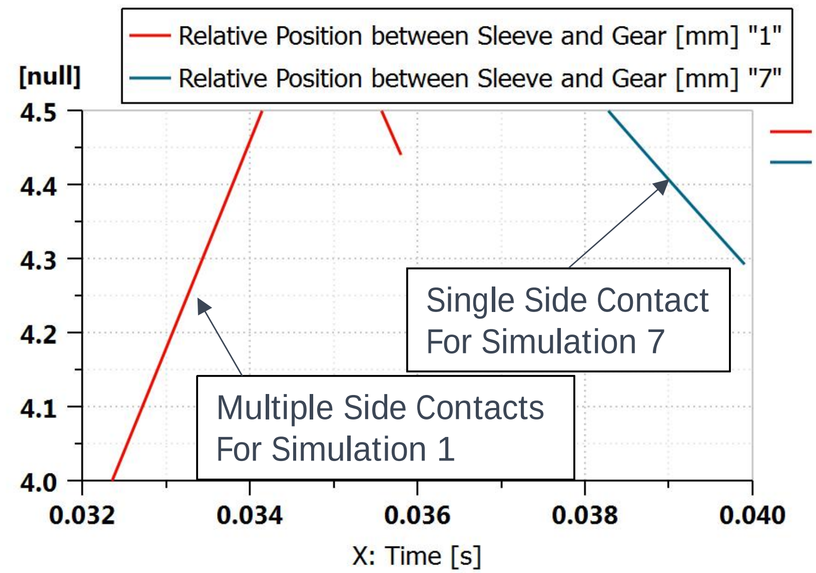
Side Contacts:

Between Sleeve Displacement 6-8 mm

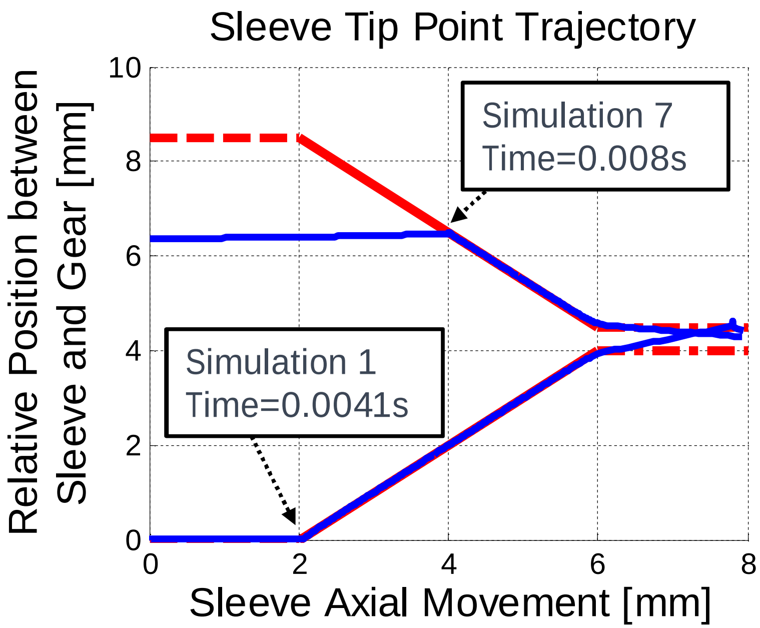
Sleeve Tip Point Hits both 4mm and 4.5 mm on relative displacement

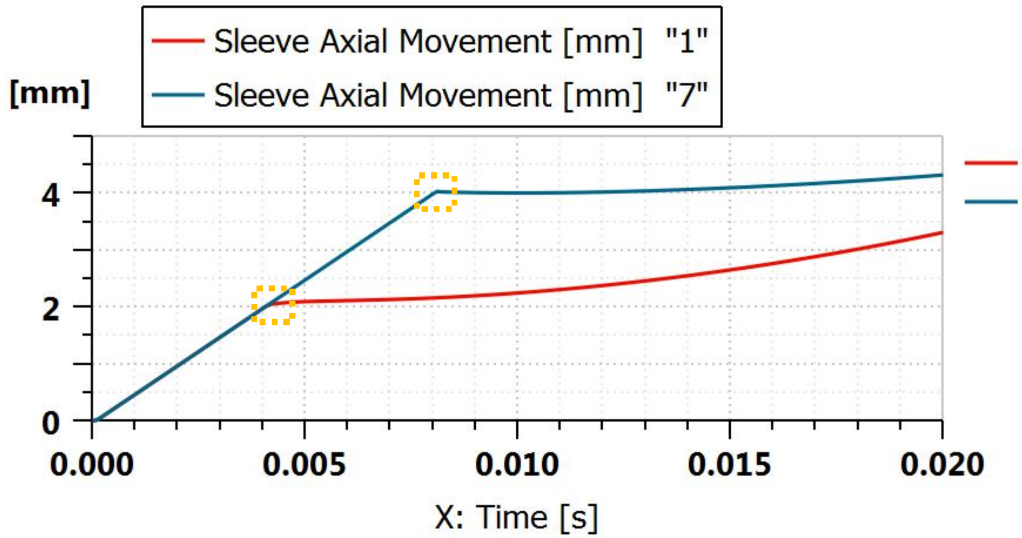




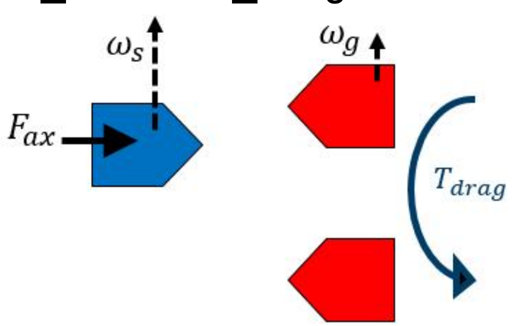


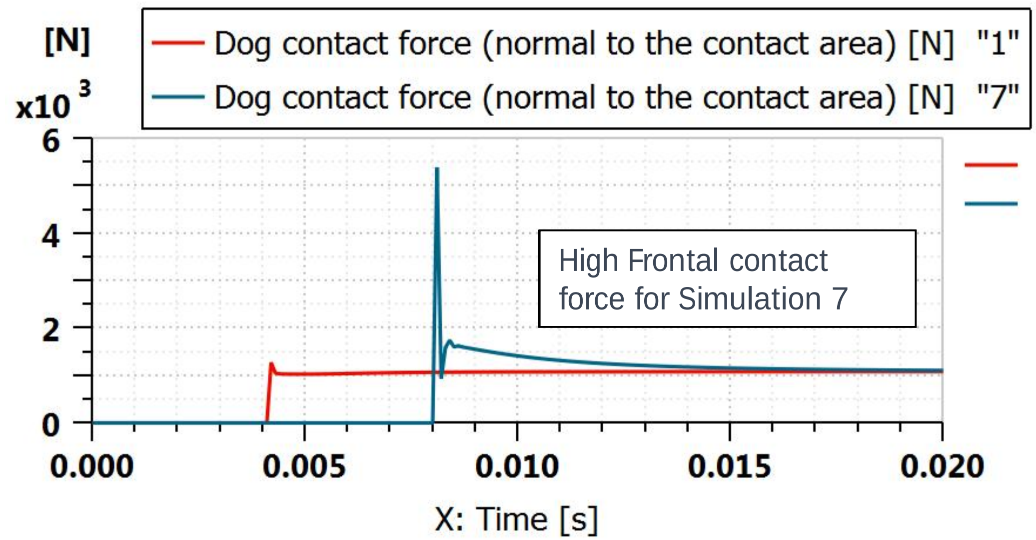
Frontal Contact Force





T_em=0; T_drag=15 Nm





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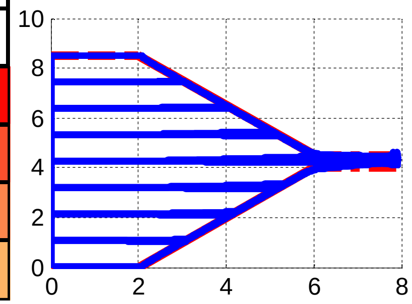
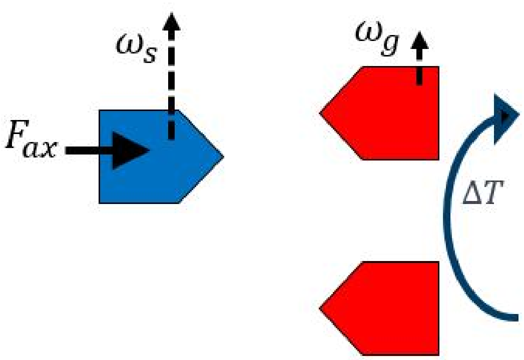
Batch Simulation Results

Engagement Time [ms]								
T_EM [Nm]	Sim 1	Sim 2	Sim 3	Sim 4	Sim 5	Sim 6	Sim 7	Sim 8
0	35,8	31,7	27,0	21,7	17,0	33,2	39,9	44,7
5,5	37,1	32,0	28,6	23,2	15,9	30,3	36,5	40,7
11	41,3	34,0	30,4	24,9	15,9	27,9	33,7	37,6
16,5	45,2	36,3	32,6	26,9	15,9	25,8	31,4	35,0



More Closer to center the simulation is started more quicker is engagement time

Maximum Frontal Contact Force [kN]			
$\|\Delta\, Torque\|\ [Nm]$	Sim 6	Sim 7	Sim 8
15	4,1	5,4	3,5
4	4,0	4,1	4,0
1,5	3,2	2,5	2,9



$|\Delta T| = |T_{em} - T_{drag}|$ and

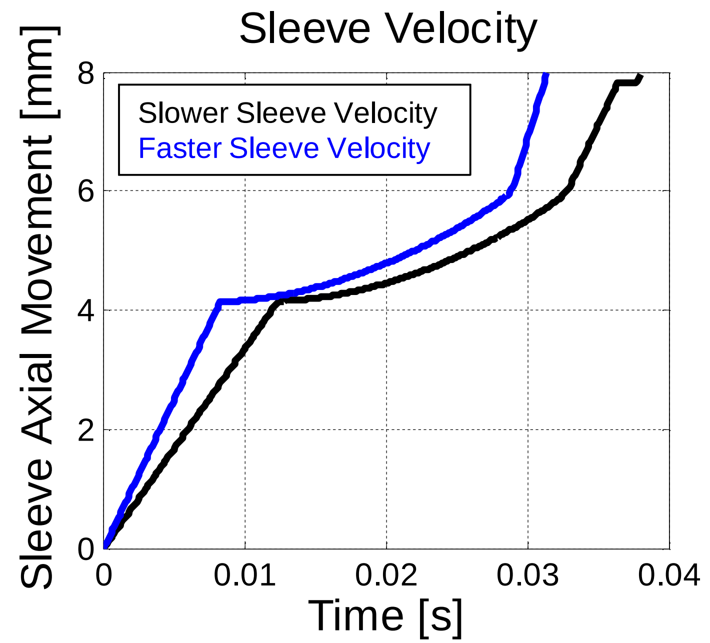
$|\Delta T| \downarrow \underset{implies}{\Longrightarrow} Maximum\ Frontal\ Contact\ Force \downarrow$

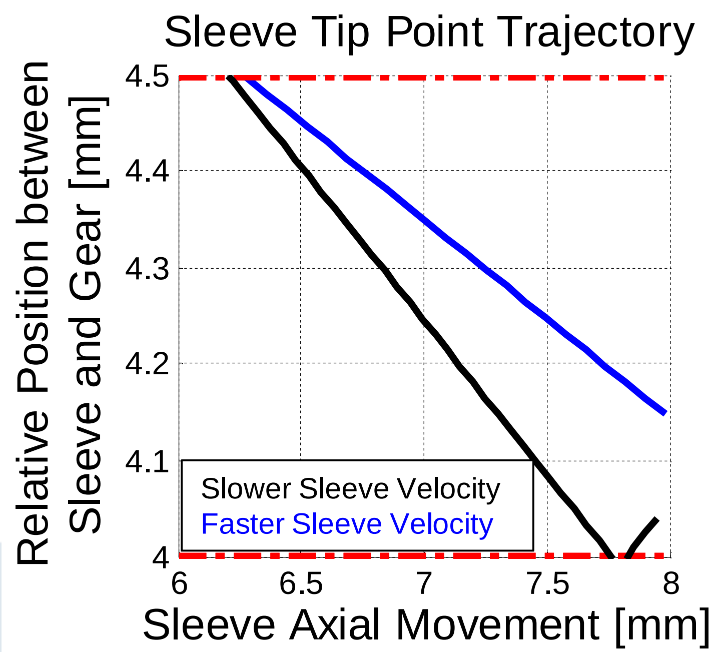
Batch Simulation Results

Existance of Multiple Side Contacts								
T_EM [Nm	Sim 1	Sim 2	Sim 3	Sim 4	Sim 5	Sim 6	Sim 7	Sim 8
0	1	1	0	0	0	0	0	0
5,5	1	0	0	0	0	0	0	0
11	0	0	0	0	0	0	0	0
16,5	0	0	0	0	0	0	0	0

Reducing Sleeve Velocity

Existance of Multiple Side Contacts								
T_EM [Nm	Sim 1	Sim 2	Sim 3	Sim 4	Sim 5	Sim 6	Sim 7	Sim 8
0	1	1	1	1	0	0	0	0
5,5	1	1	1	0	0	0	0	0
11	1	1	1	0	0	0	0	1
16,5	1	1	1	0	0	0	1	1





Conclusions

A simulation tool is developed based on AMESim which can:

1. Simulate in detail the post synchronization phases of synchronizer
2. The tool can be used to evaluate various
    1. Synchronizer teeth geometries
    2. Actuation systems
3. The outputs from the tools can be used to evaluate
    1. Engagement times
    2. Noise potential in post synchronization phases
    3. Wear in synchronizer teeth

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