Modelling and Analysis of the Pluriel Roof System

A dynamic Multi-Body Approach

SayField International
&
Inalfa Roof Systems

2001

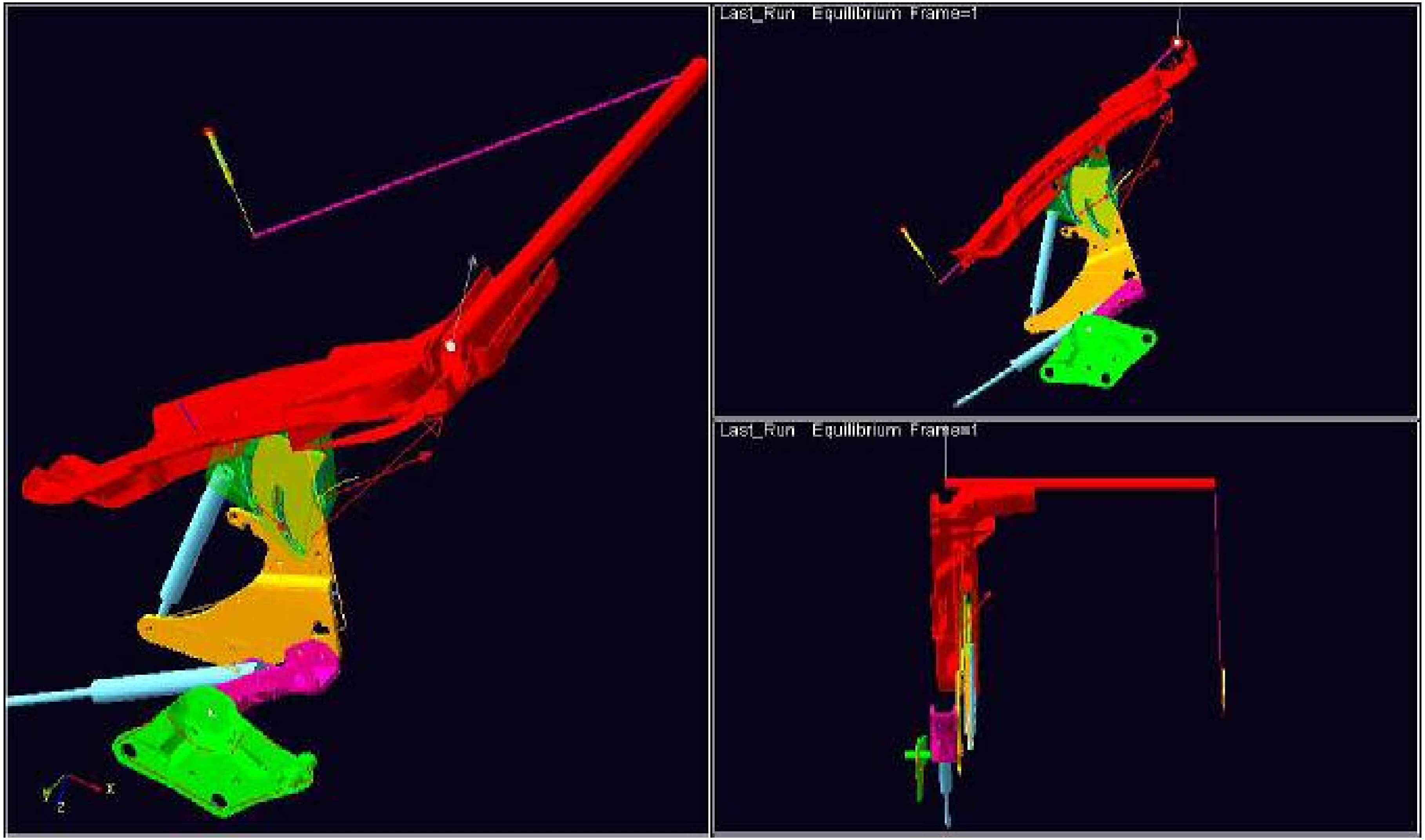
Project Approach

- Customized ADAMS simulation environment to automate and support:
  - Different types of analyses: kinematic, static dynamic
  - Different model complexities:
    - Rigid<-> Flexible
    - Pin contact method
  - Creating of new parameter settings:
    - Slot geometry creation through kinematics,
    - Automated geometry changes of model components,
    - ....

Contents

- Model layout & method explanation
- Verification of the pin-slot model method
- Verification of the flexible model
- Used simulation approach:
  - Focus on opening-closing hand force required
  - Test criteria:
    1. Hand force magnitude
    2. Locking effect at full pre-lift cassette
  - Verification of the measurements
- Results of parameter studies performed

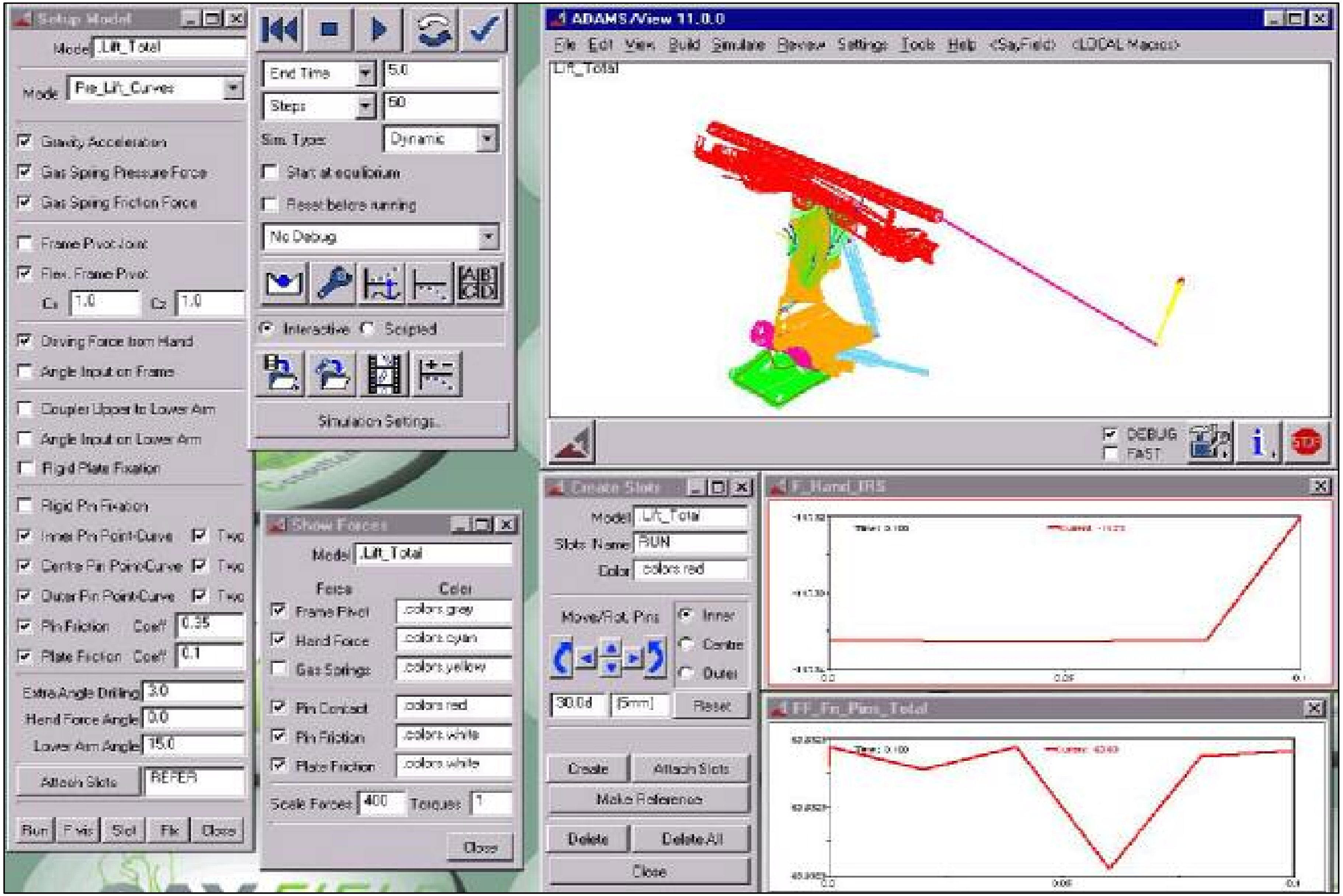
Simulation Model Layout



Modeling Method

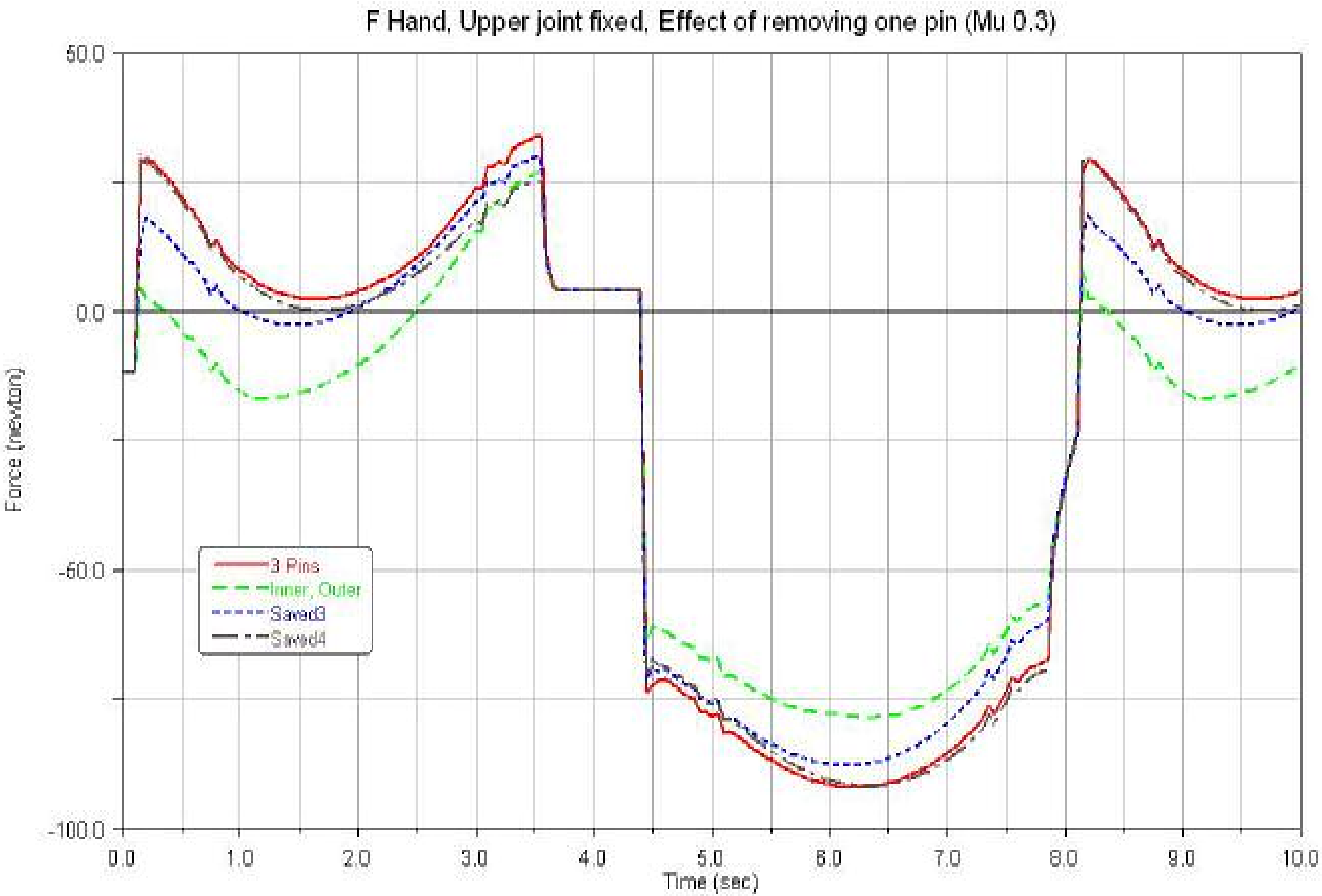
- Geometry based on Inalfa IGES files
- Arm Force through prescribed lever rotation
- Open-close sequence in 10 seconds
- Friction is included at pins, plates and joints
- Half system is modelled, symmetry L-R
- Top Pivot can be one-sided x and free z
- Gas spring forces according to specified linear approach
- All force load effects can be switched off:
  - Contributions of components is clear
  - Possible to analyse self-locking effect

IRS Customised - ADAMS

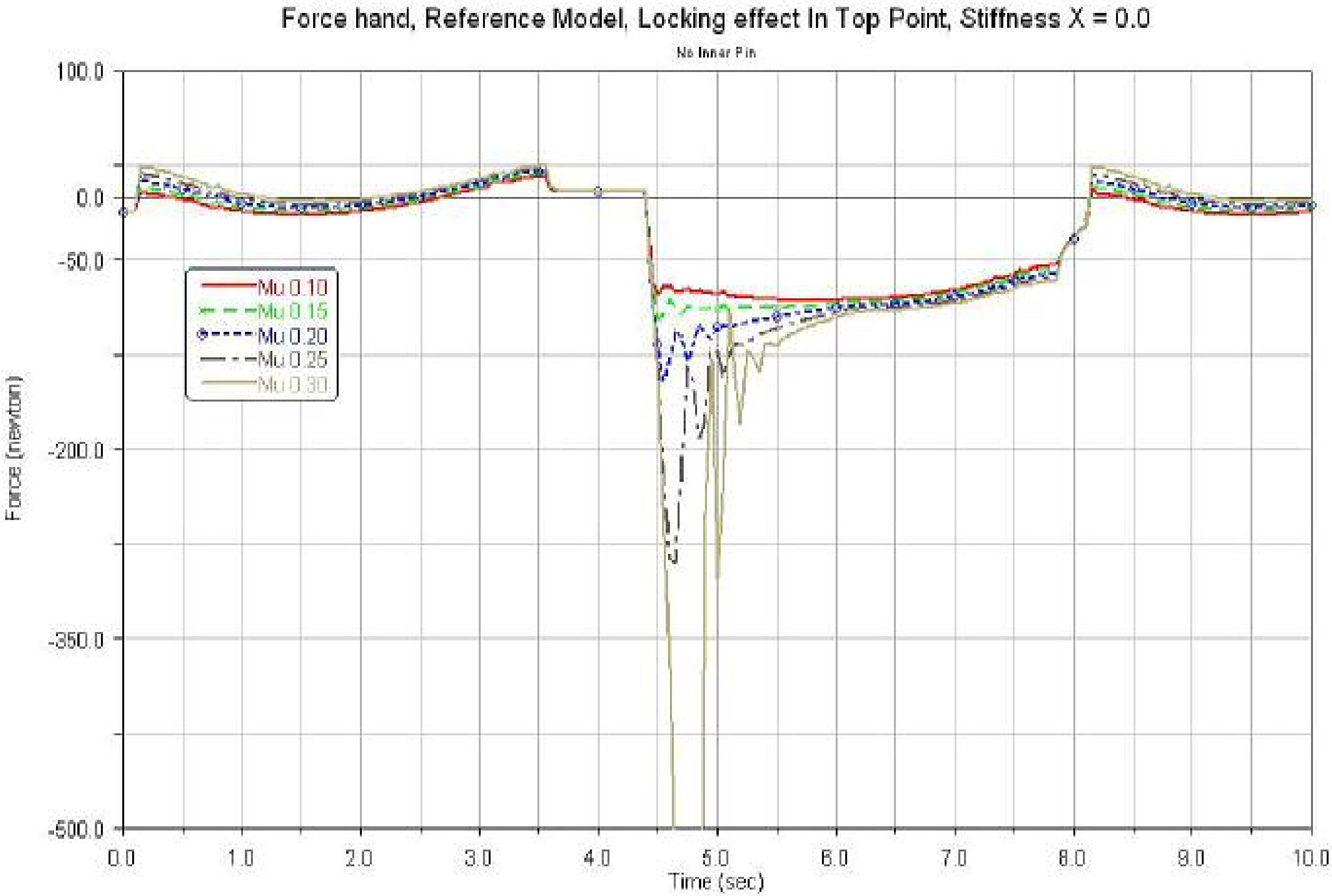


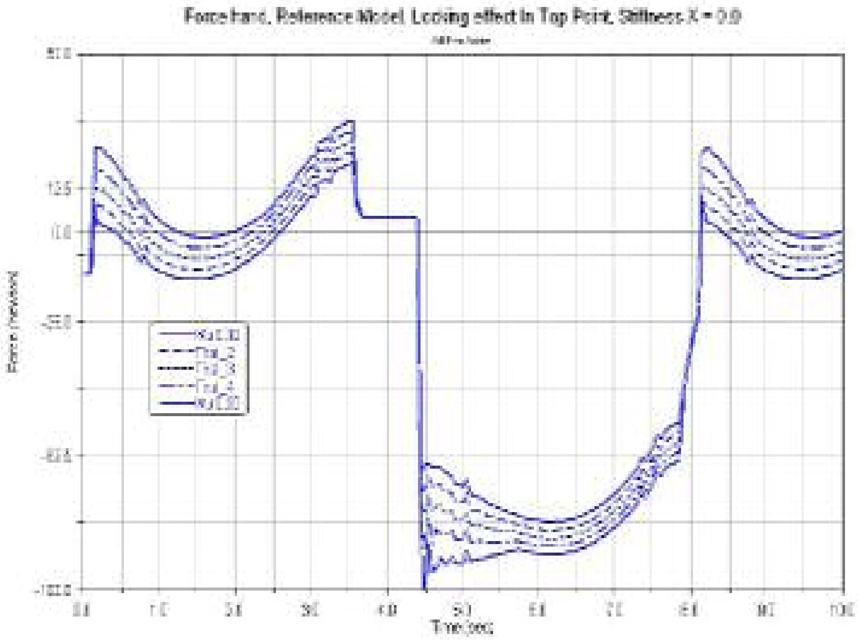
Pin-Slot Model, I

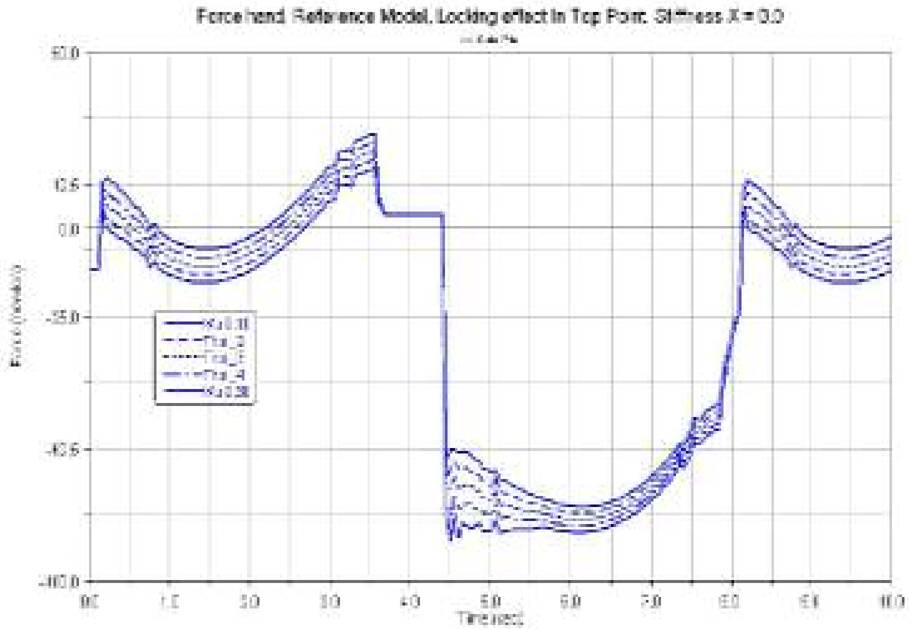
- Activating pins has large effect on locking phenomenon ($Cz = 0$, $Cx = 0$)
- Activating pins has small effect on hand force required ($Cx = Cz = 1$)
- Friction coefficient pin-plate has large effect on locking effect

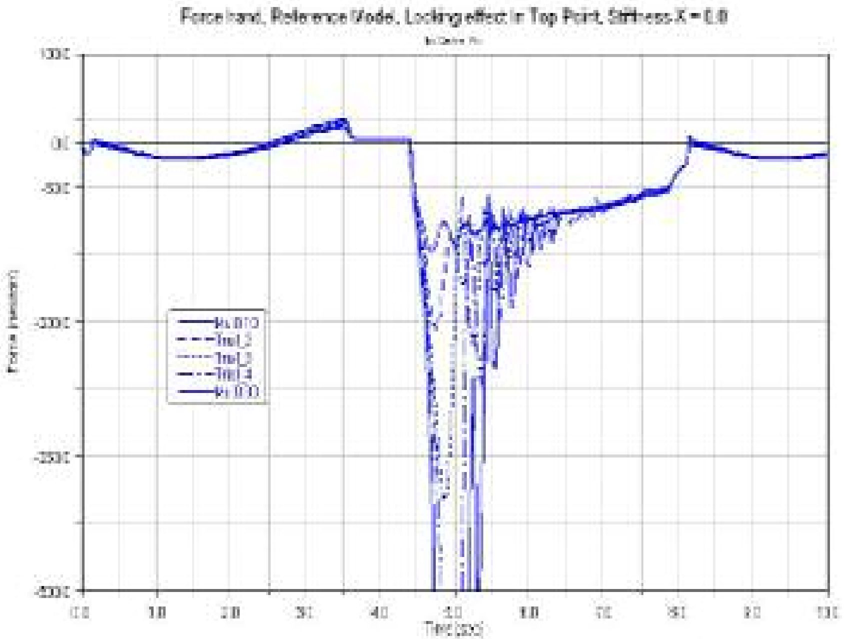


F Hand, Upper joint fixed, Effect of removing one pin (Mu 0.3)
50.0
0.0
-50.0
-100.0
Force (newton)
0.0
1.0
2.0
3.0
4.0
5.0
6.0
7.0
8.0
9.0
10.0
Time (sec)
3 Pins
Inner, Outer
Saved3
Saved4

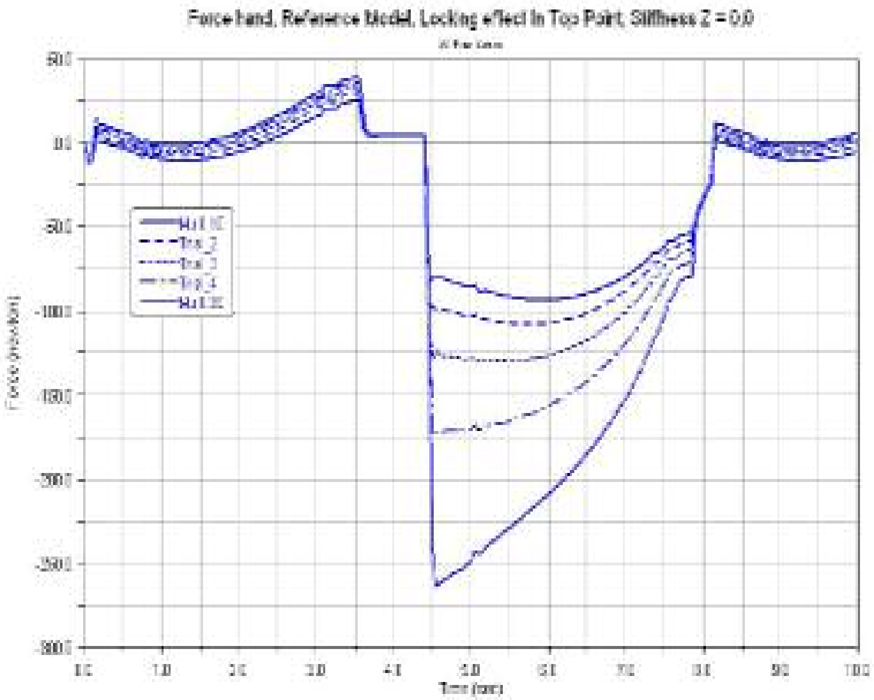

Force hand, Reference Model, Locking effect In Top Point, Stiffness X = 0.0
No Inner Pin
100.0
0.0
-50.0
-200.0
-350.0
-500.0
Force (newton)
Mu 0.10
Mu 0.15
Mu 0.20
Mu 0.25
Mu 0.30
0.0
1.0
2.0
3.0
4.0
5.0
6.0
7.0
8.0
9.0
10.0
Time (sec)

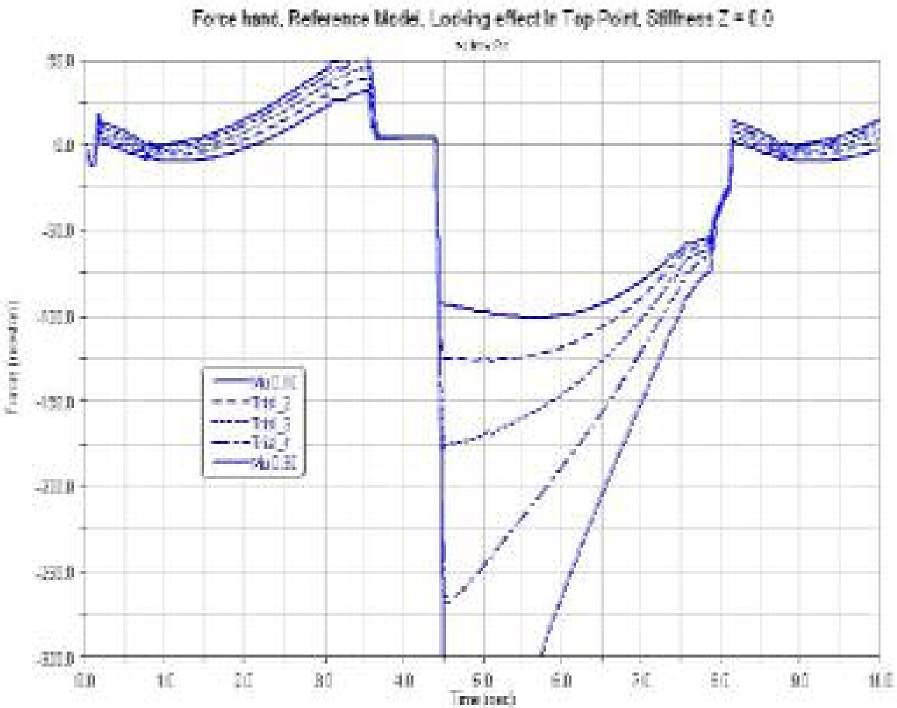


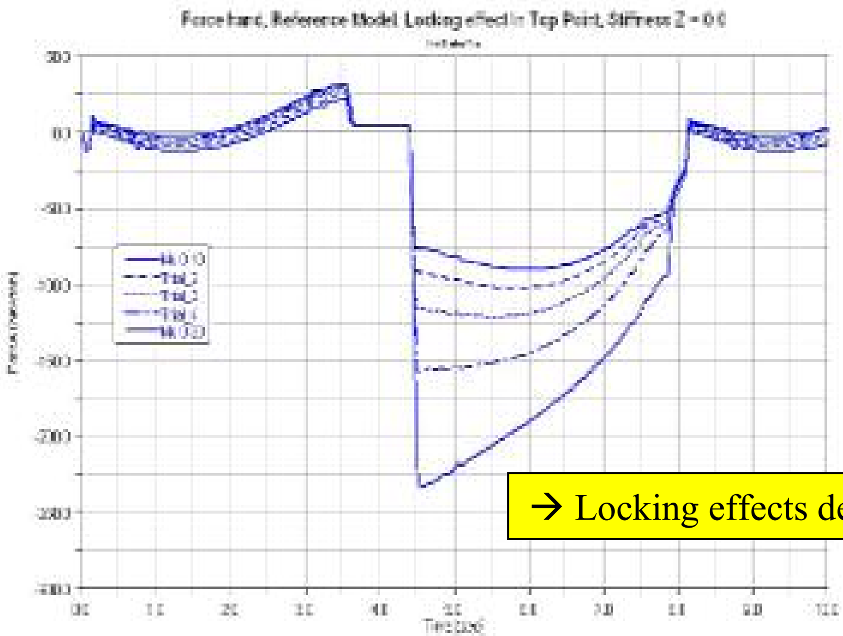


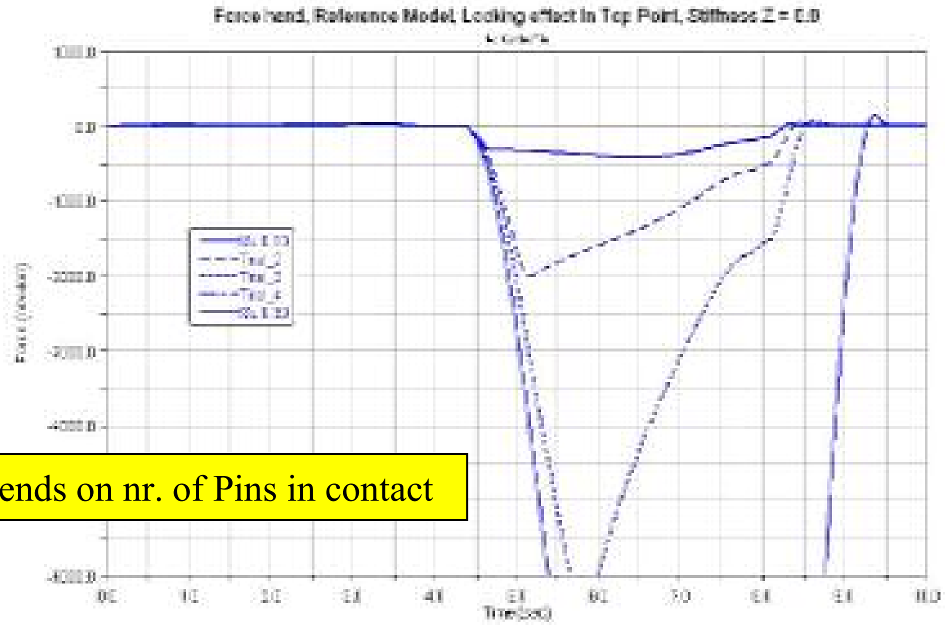


→ Locking effects depends on nr. of Pins in contact

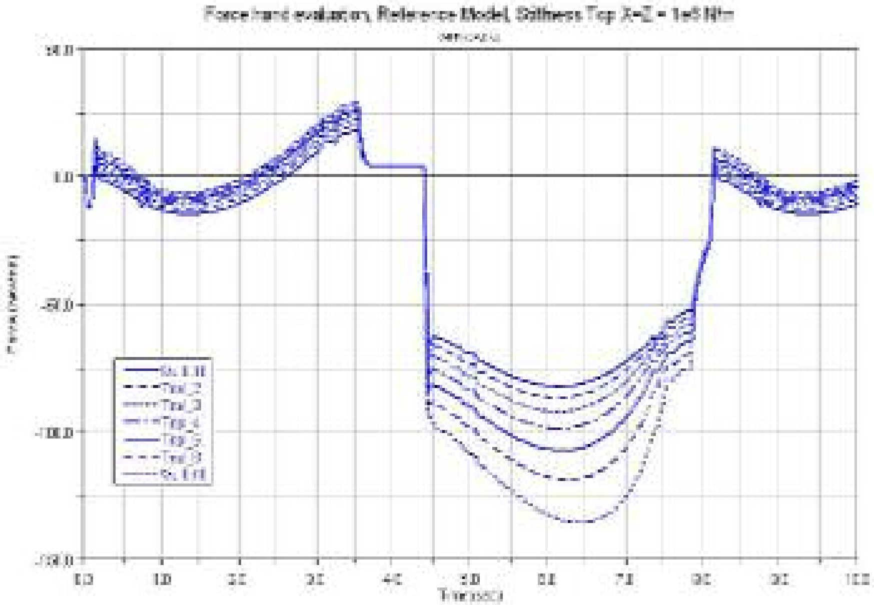


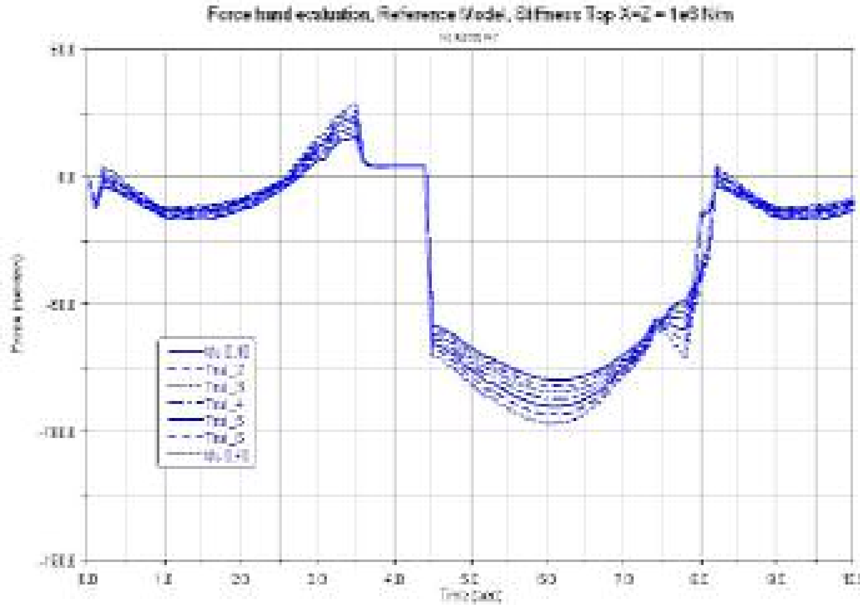




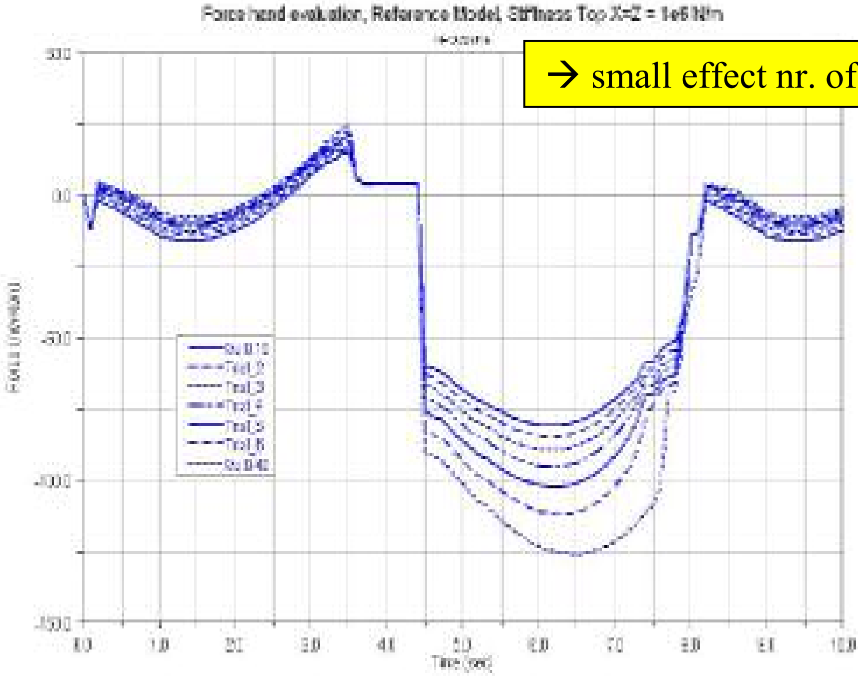


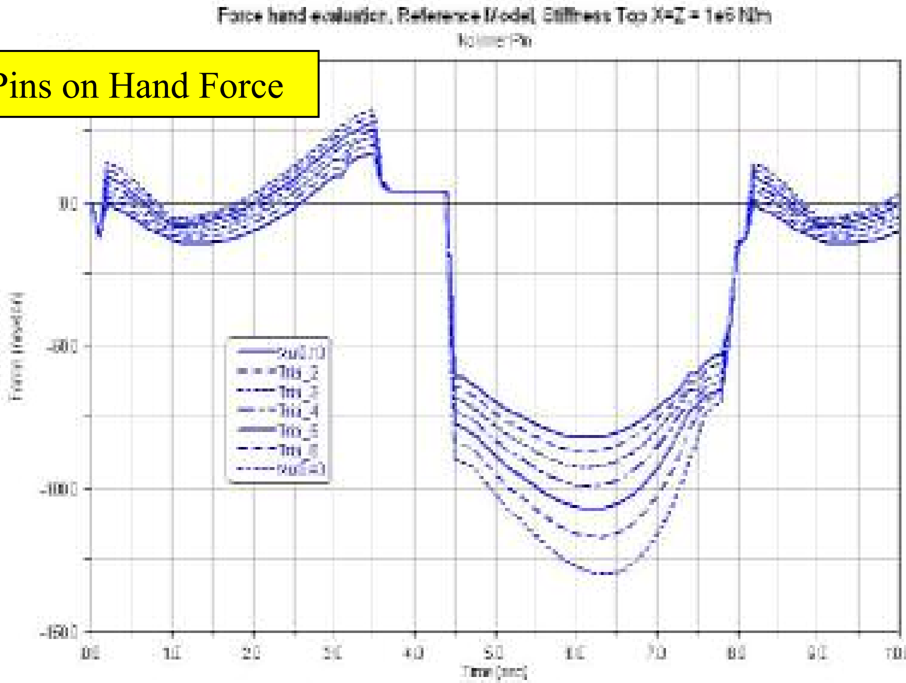
→ Locking effects depends on nr. of Pins in contact

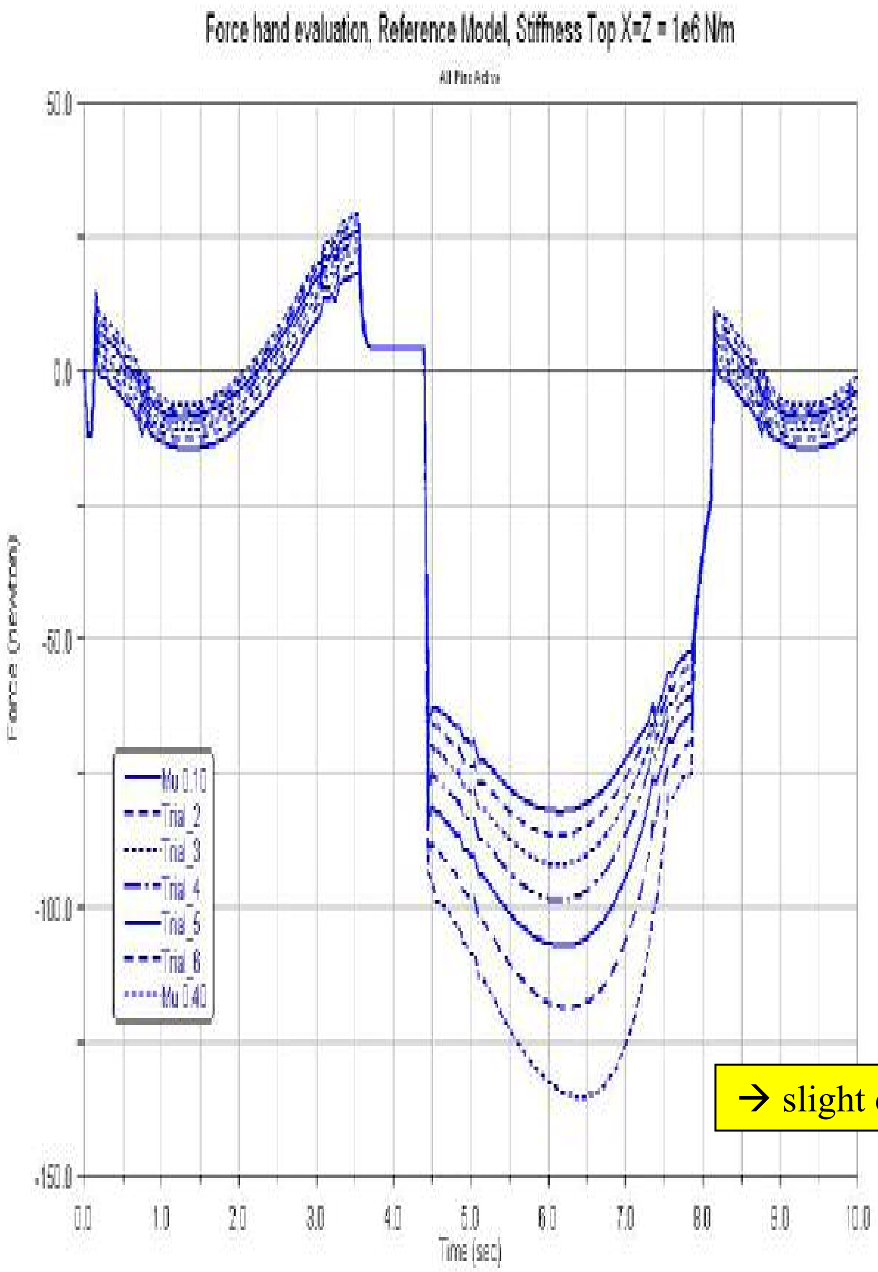


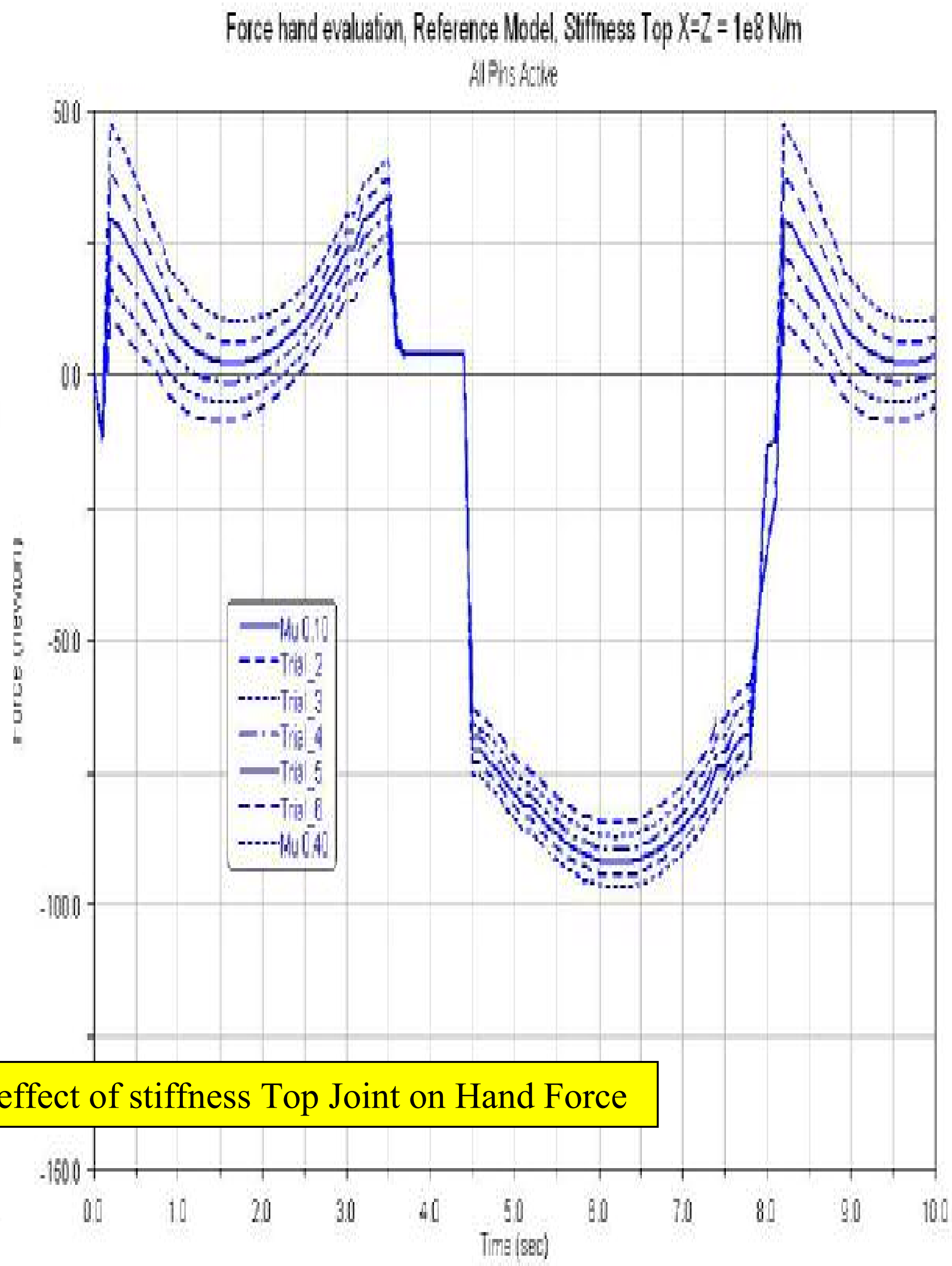


→ small effect nr. of Pins on Hand Force





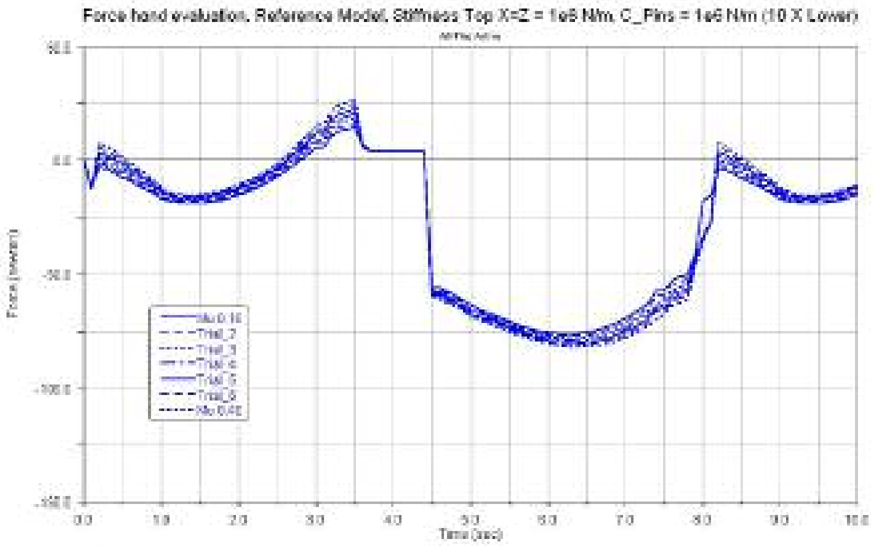


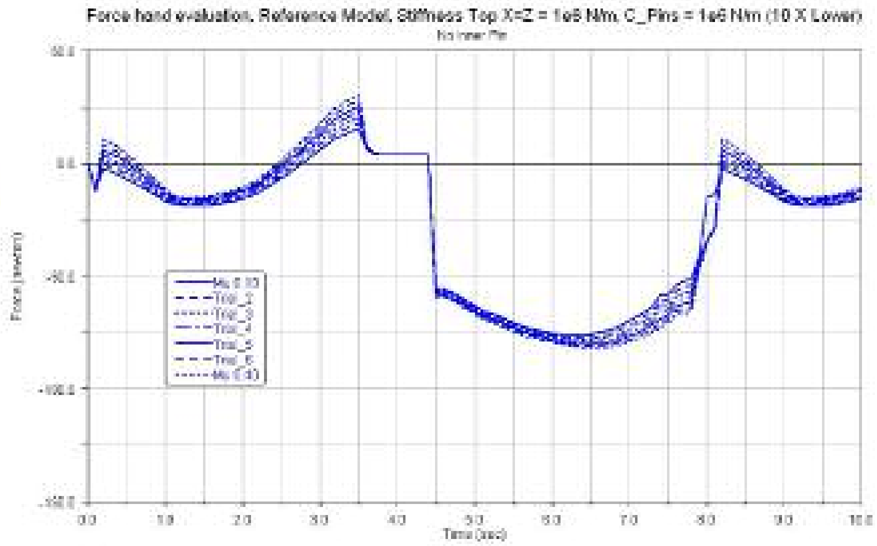


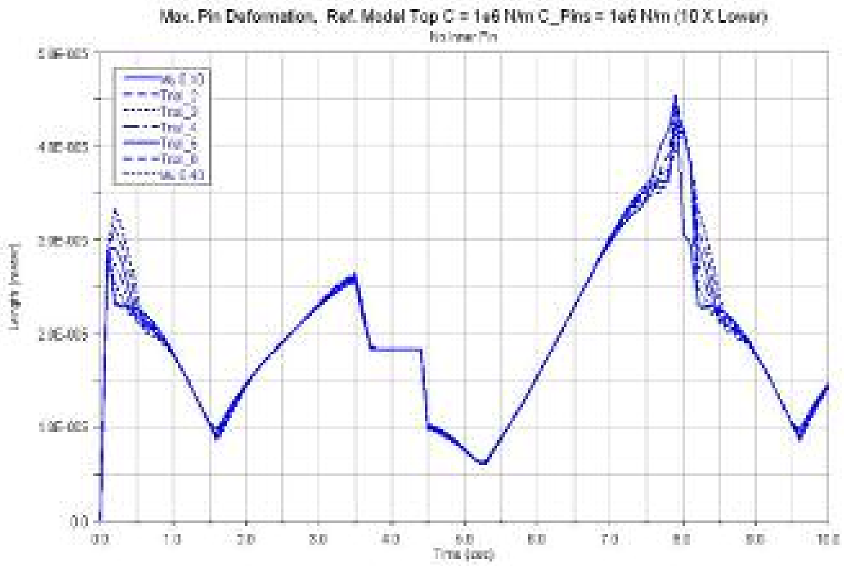
→ slight effect of stiffness Top Joint on Hand Force

Pin Slot Model, II

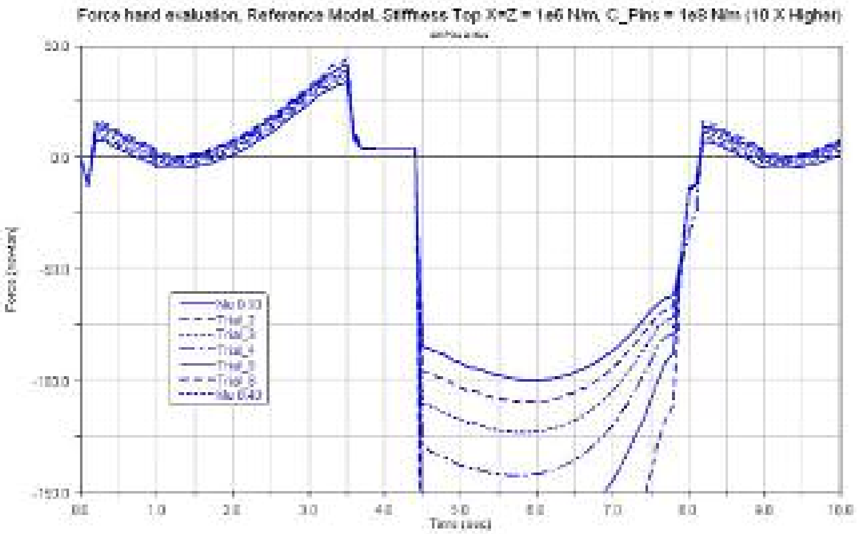
- Play in pins has effect on self-locking and hand force.
- More play is beneficial for both criteria (0.1 mm = O.K.)
- Large pin axial stiffness increases torsion stiffness of Lower Arm → bigger hand-force required

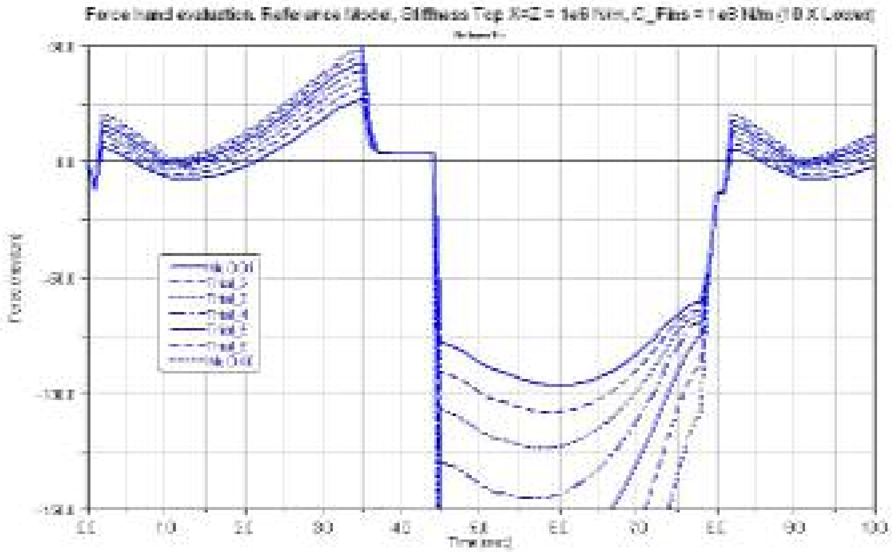


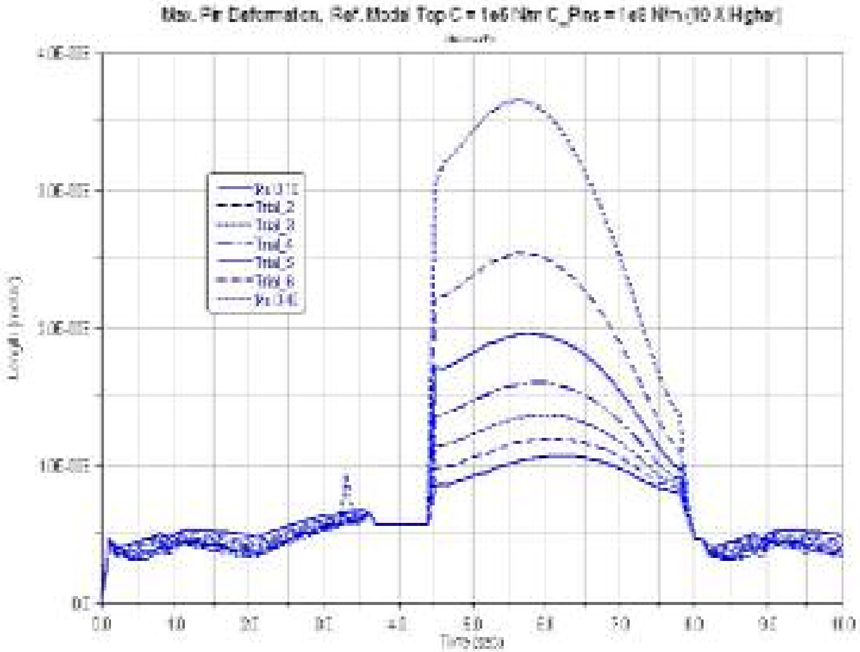




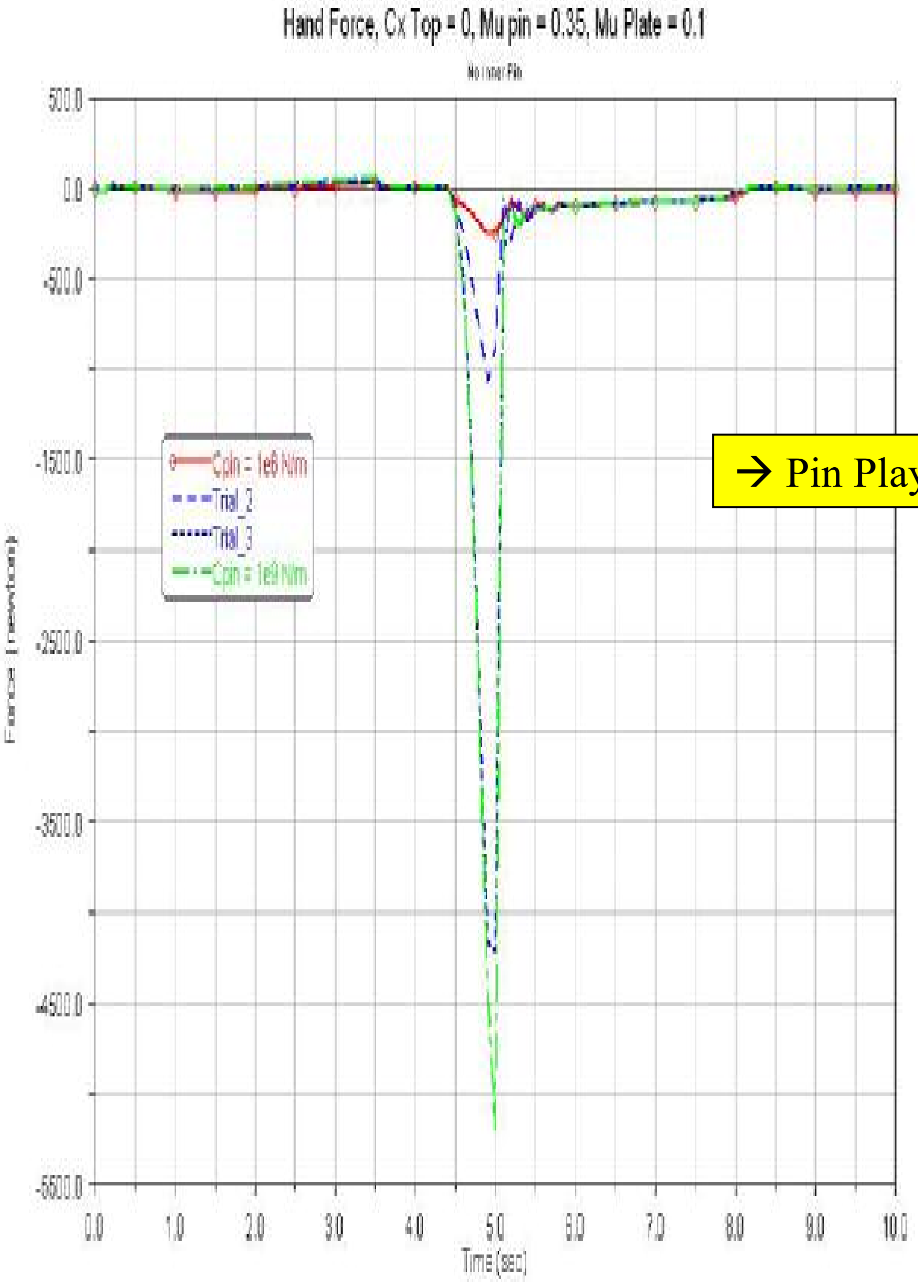
→ More Pin Play: less hand force required



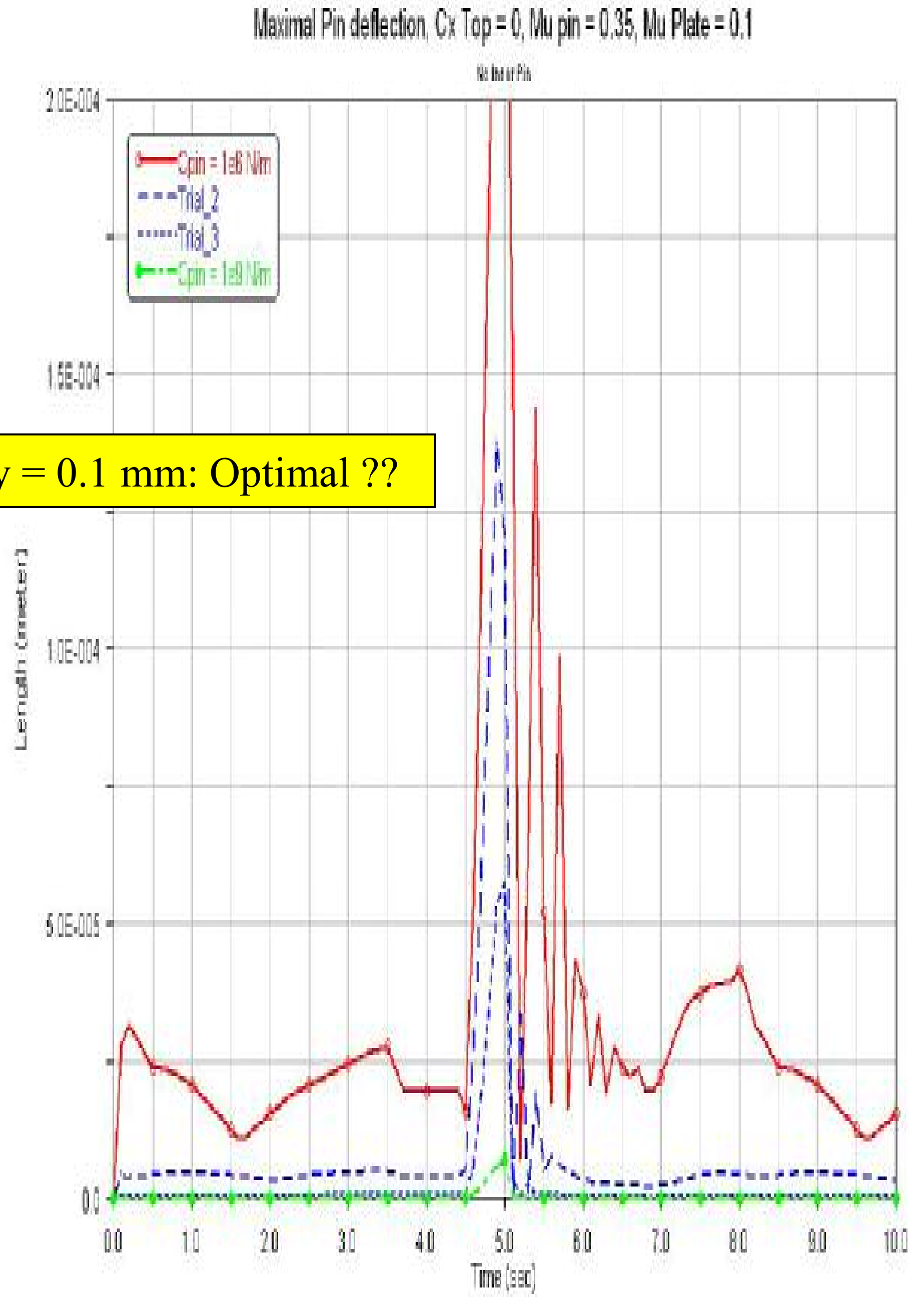


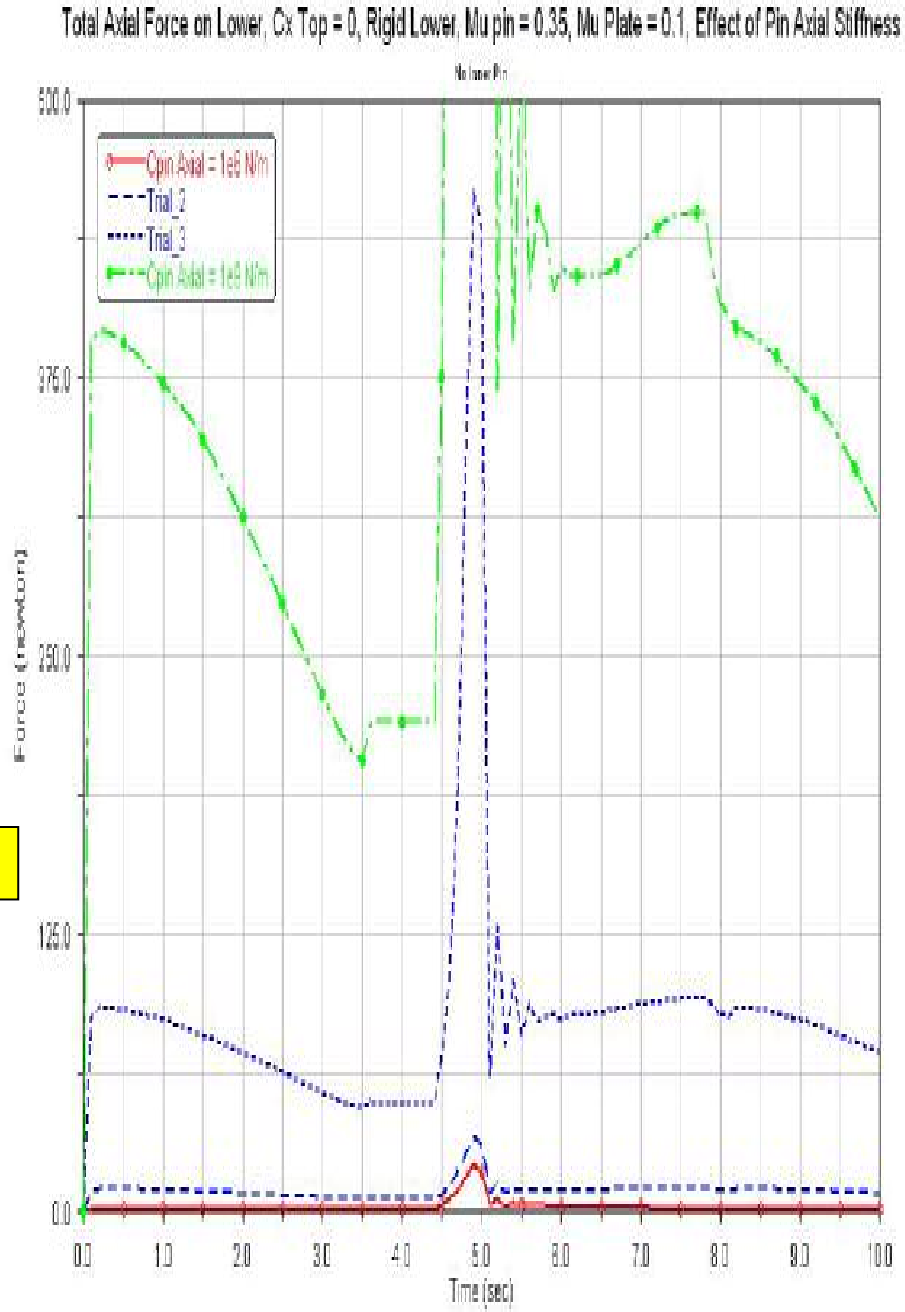


→ Less Pin Play: more hand force required

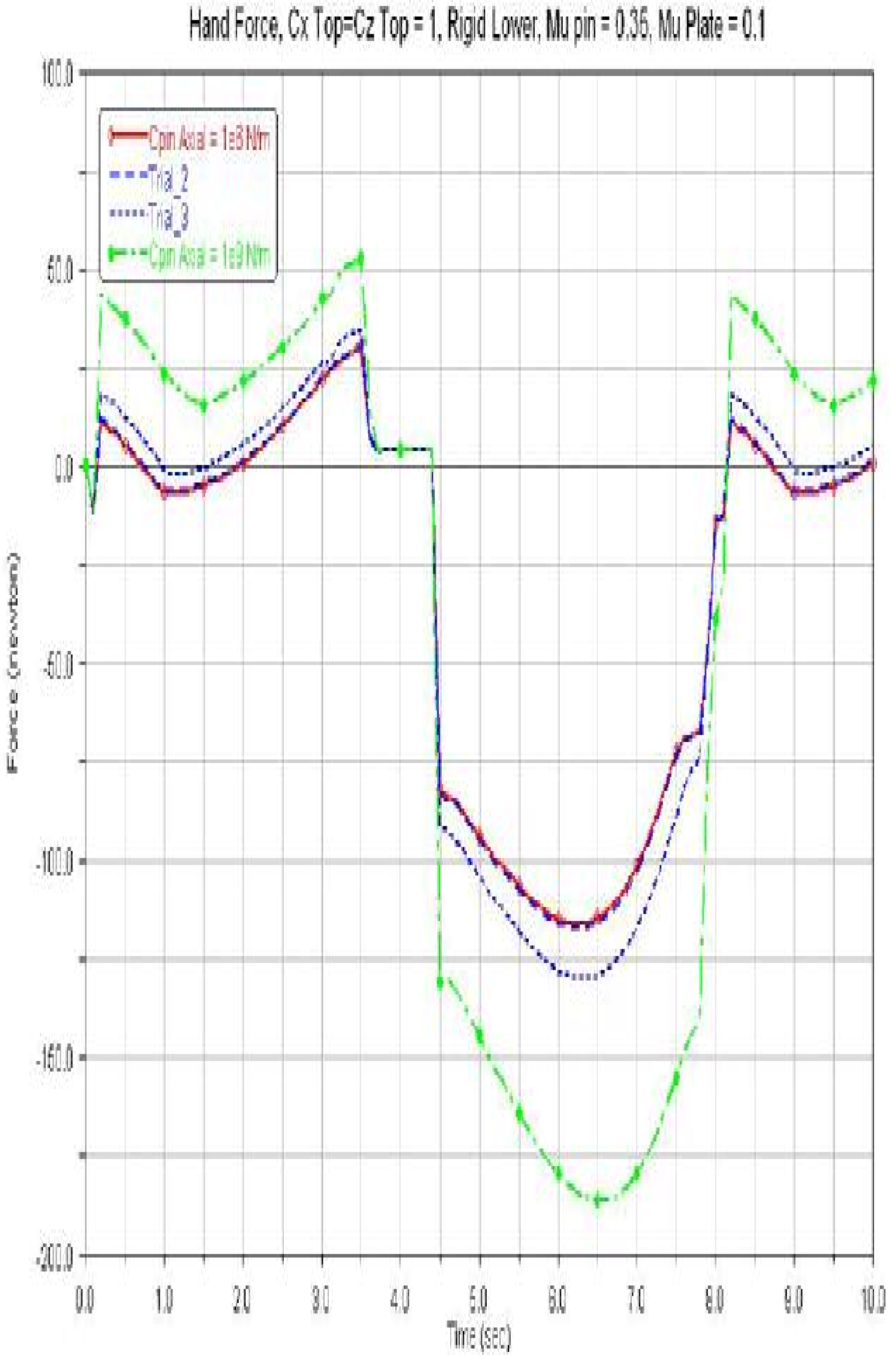


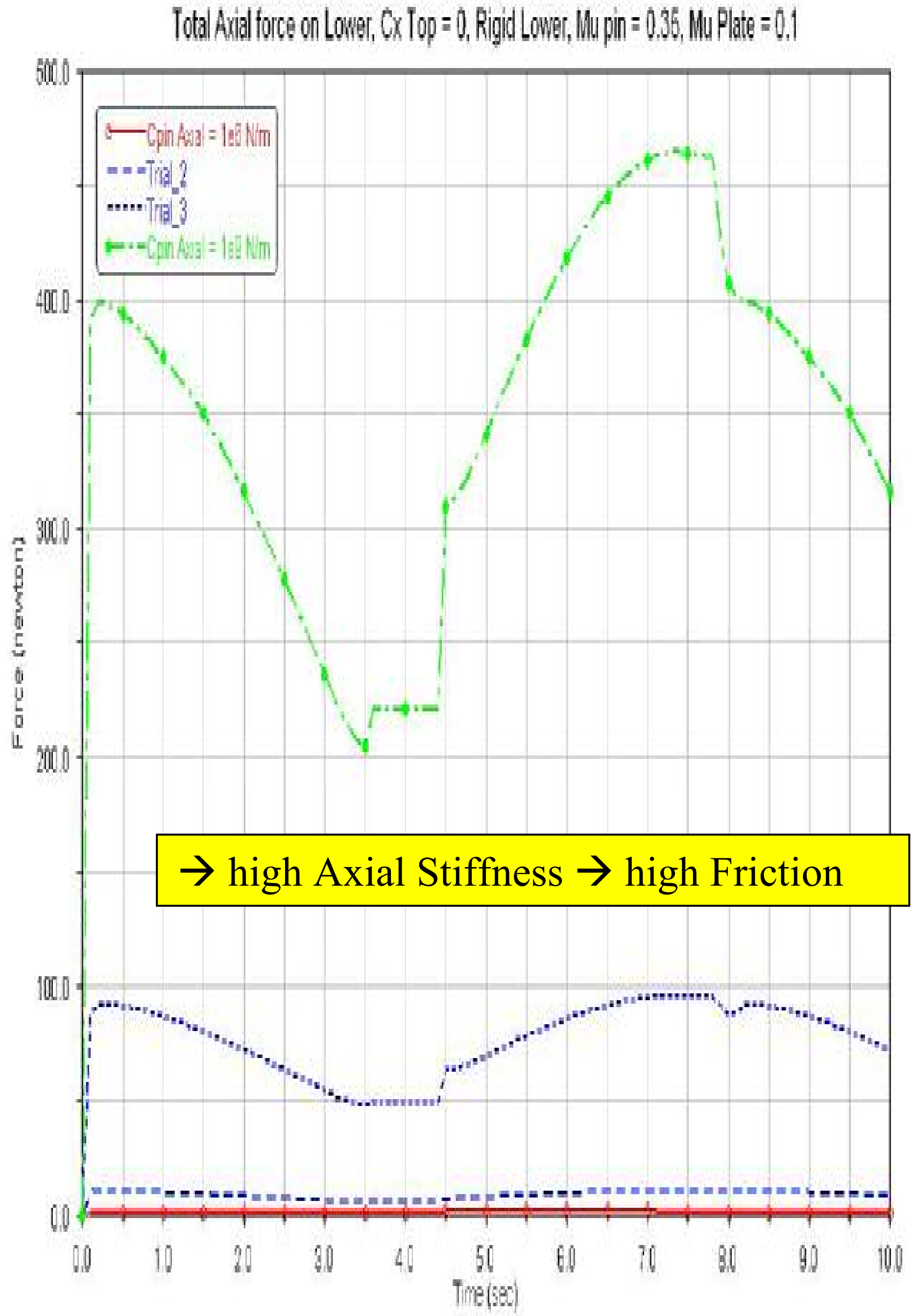
→ Pin Play = 0.1 mm: Optimal ??





→ Torsion stiff Lower arm: worse locking

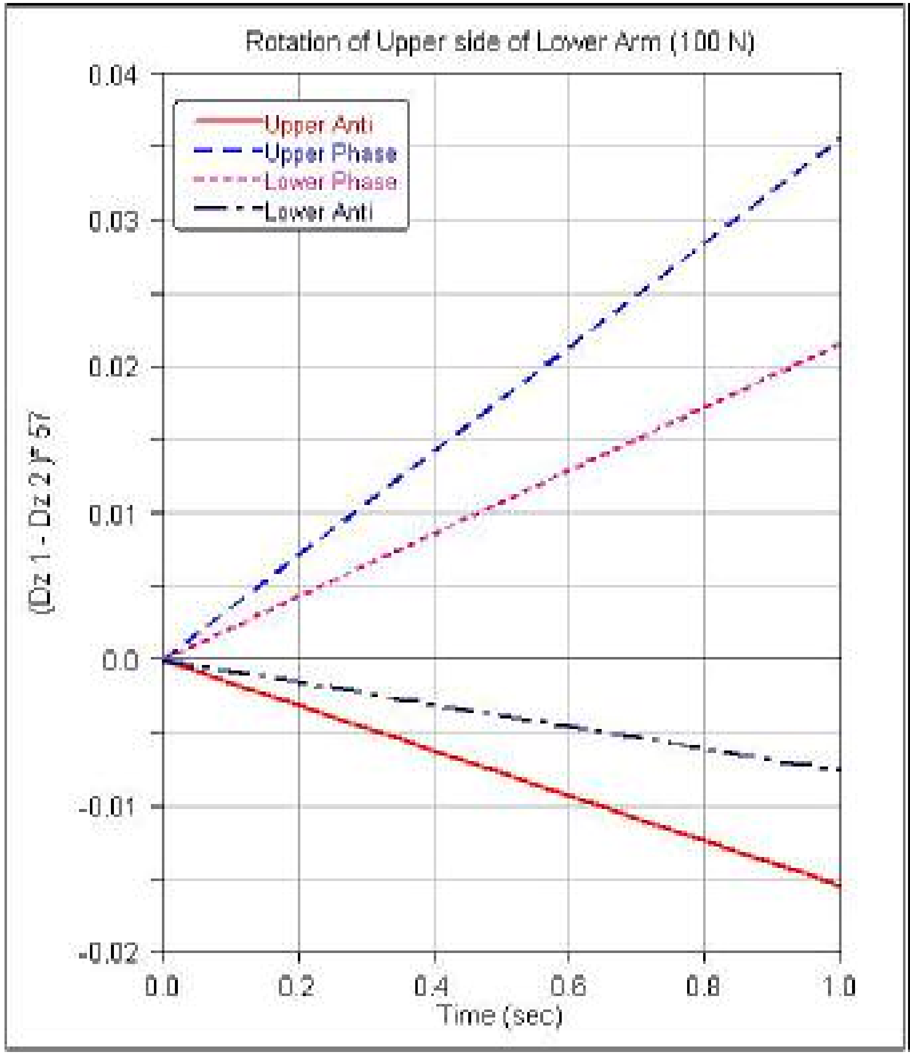

Hand Force, Cx Top=Cz Top = 1, Rigid Lower, Mu pin = 0.35, Mu Plate = 0.1
Cpin Axial = 1e8 N/m
Trial_2
Trial_3
Cpin Axial = 1e9 N/m
Force (newton)
Time (sec)

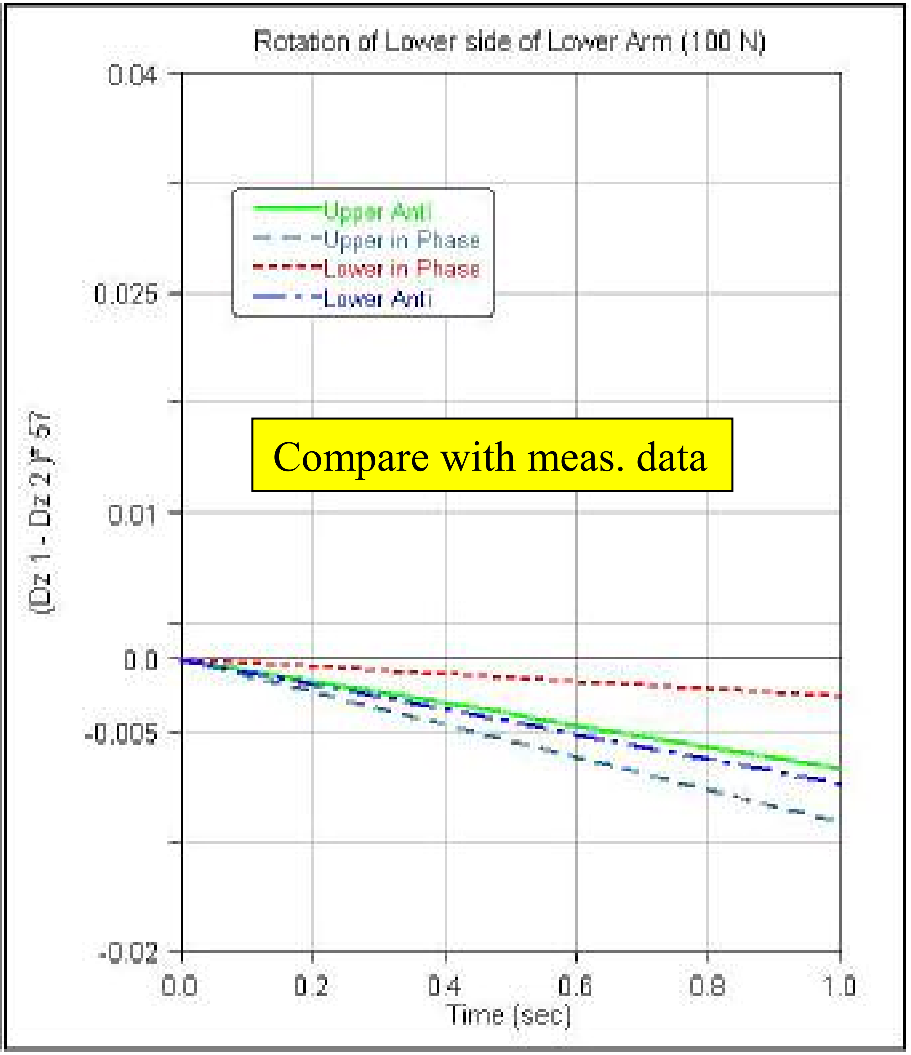

Total Axial force on Lower, Cx Top = 0, Rigid Lower, Mu pin = 0.35, Mu Plate = 0.1
Cpin Axial = 1e8 N/m
Trial_2
Trial_3
Cpin Axial = 1e9 N/m
Force (newton)
Time (sec)
→ high Axial Stiffness → high Friction

Verification of Flex Model

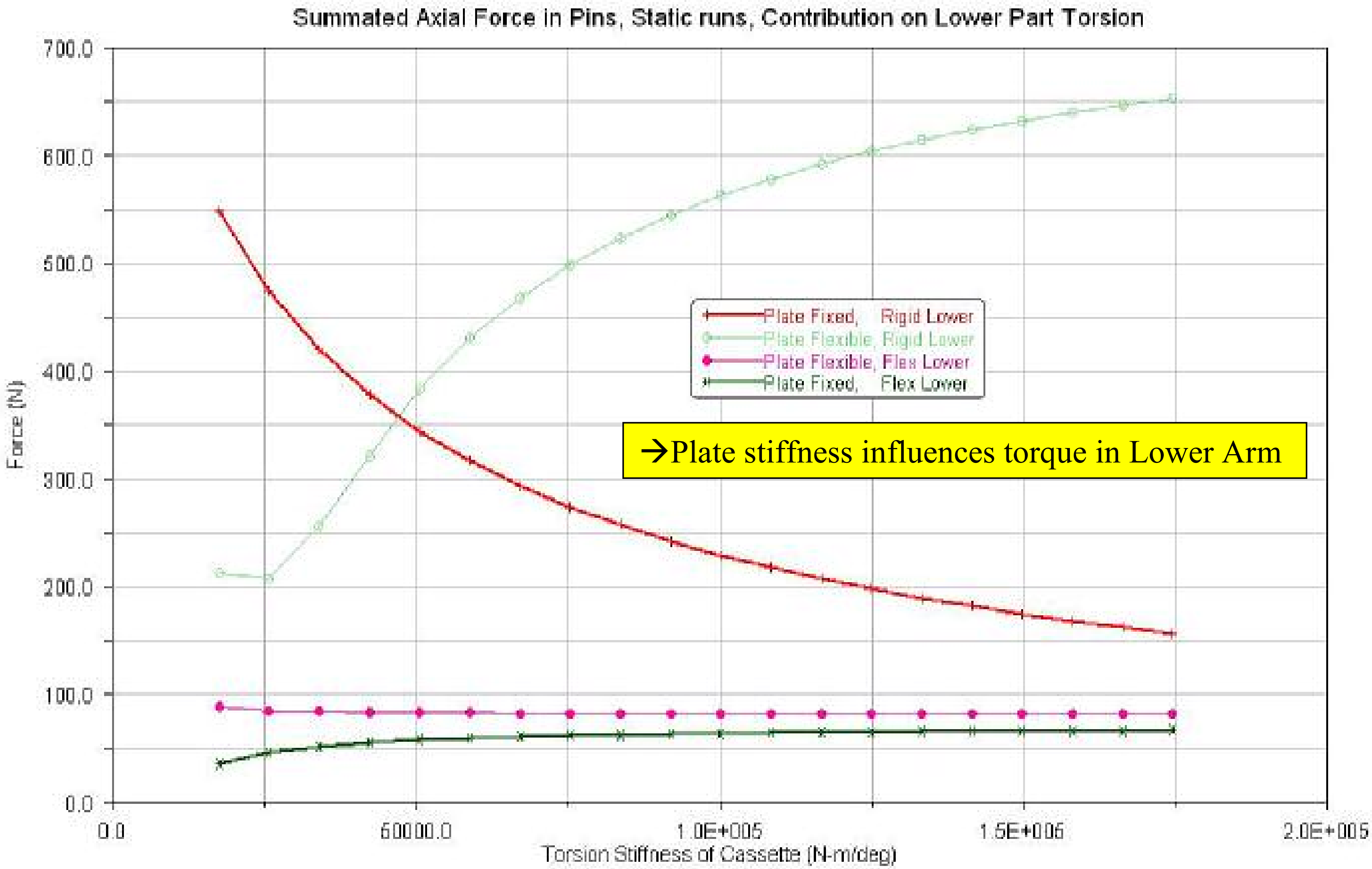
- Steady state stiffness of Flex part determined.
- Method: three rigid linings along slots
- Extra influences in Flex model:
  - Torsion Stiffness of upper Frame
  - Long. and Torsion. Stiffness of the Plate
- → Hand force increases with reasonable parameters

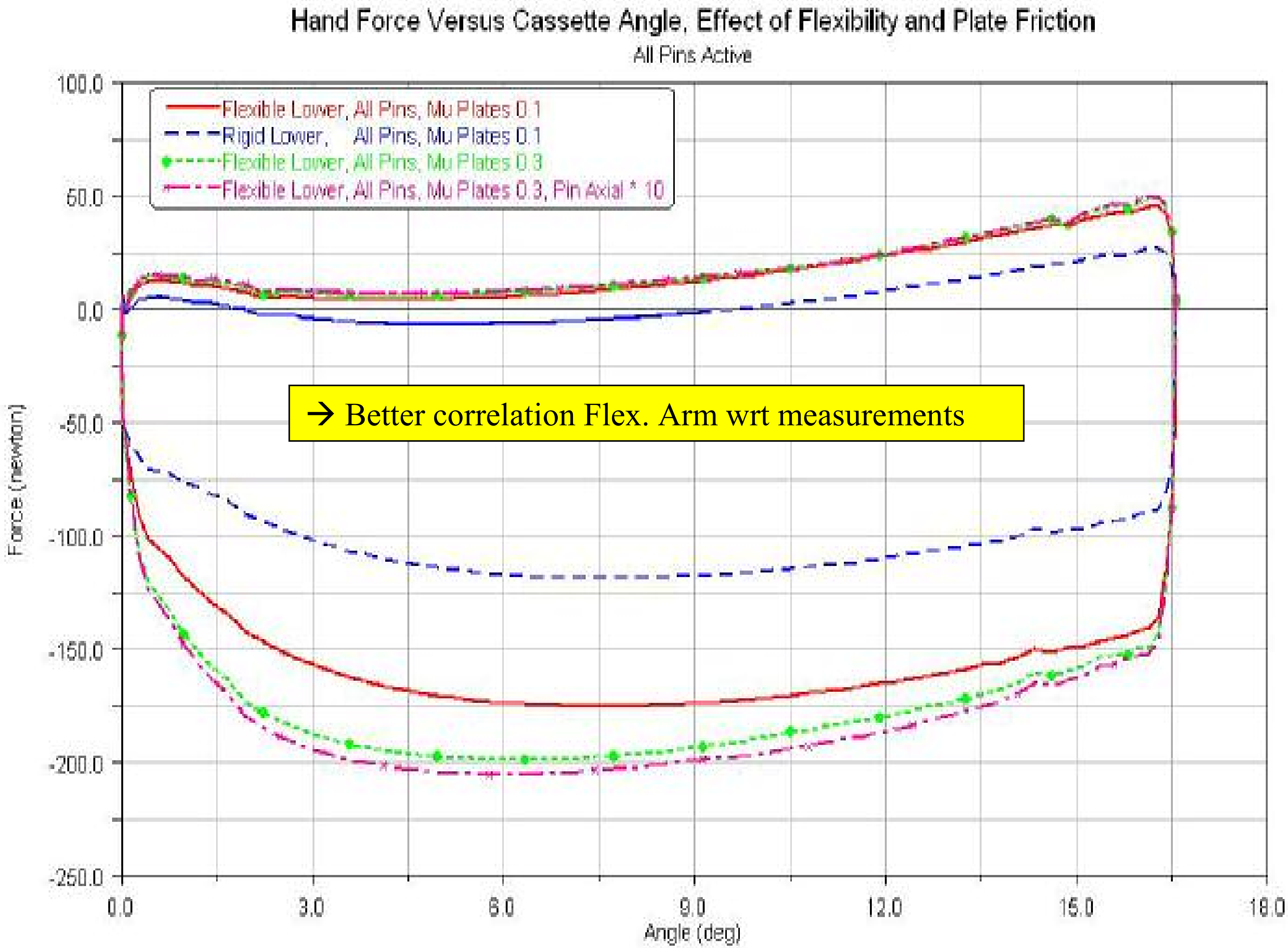
Static Analysis to determine Flex Part lateral stiffness



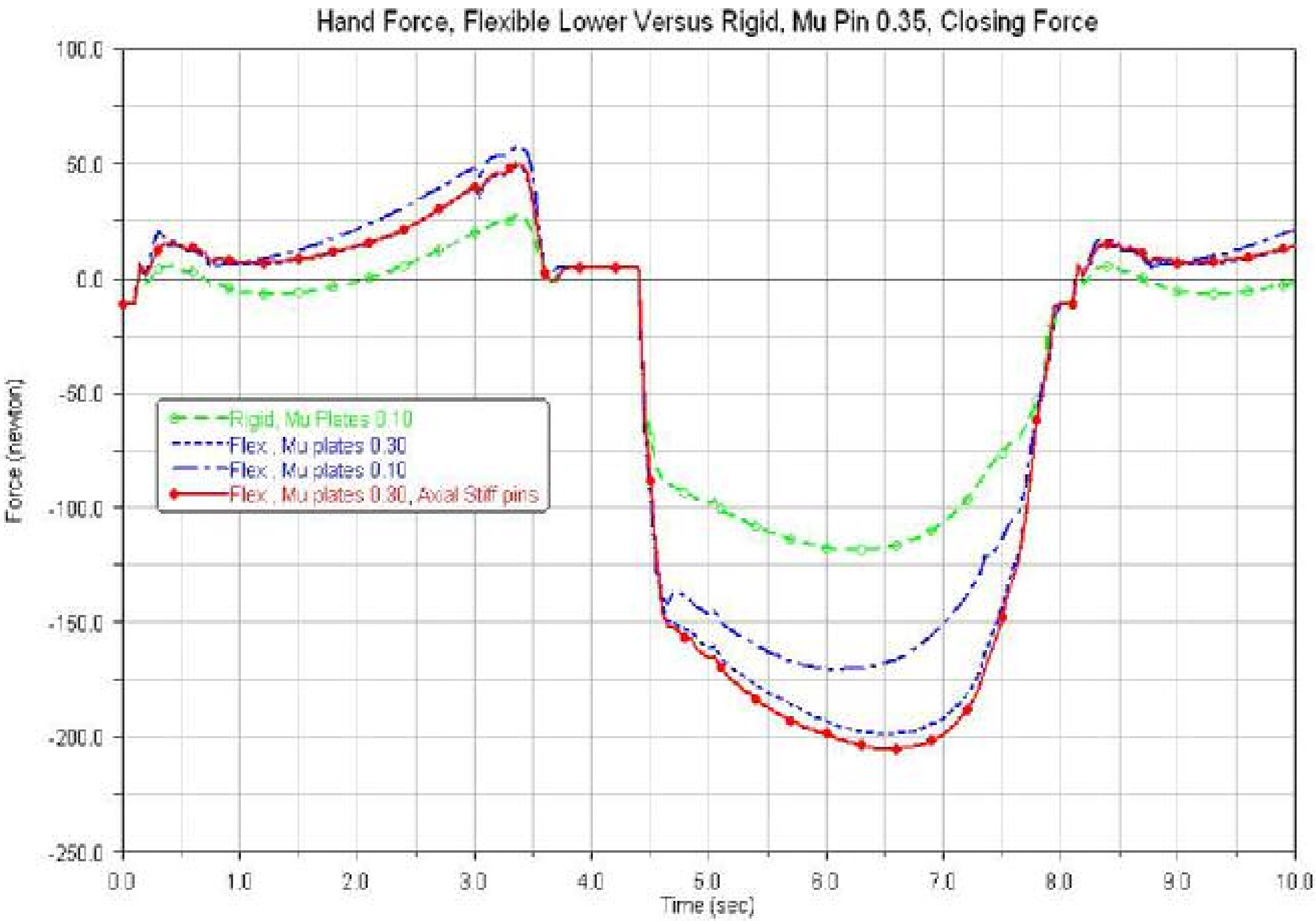


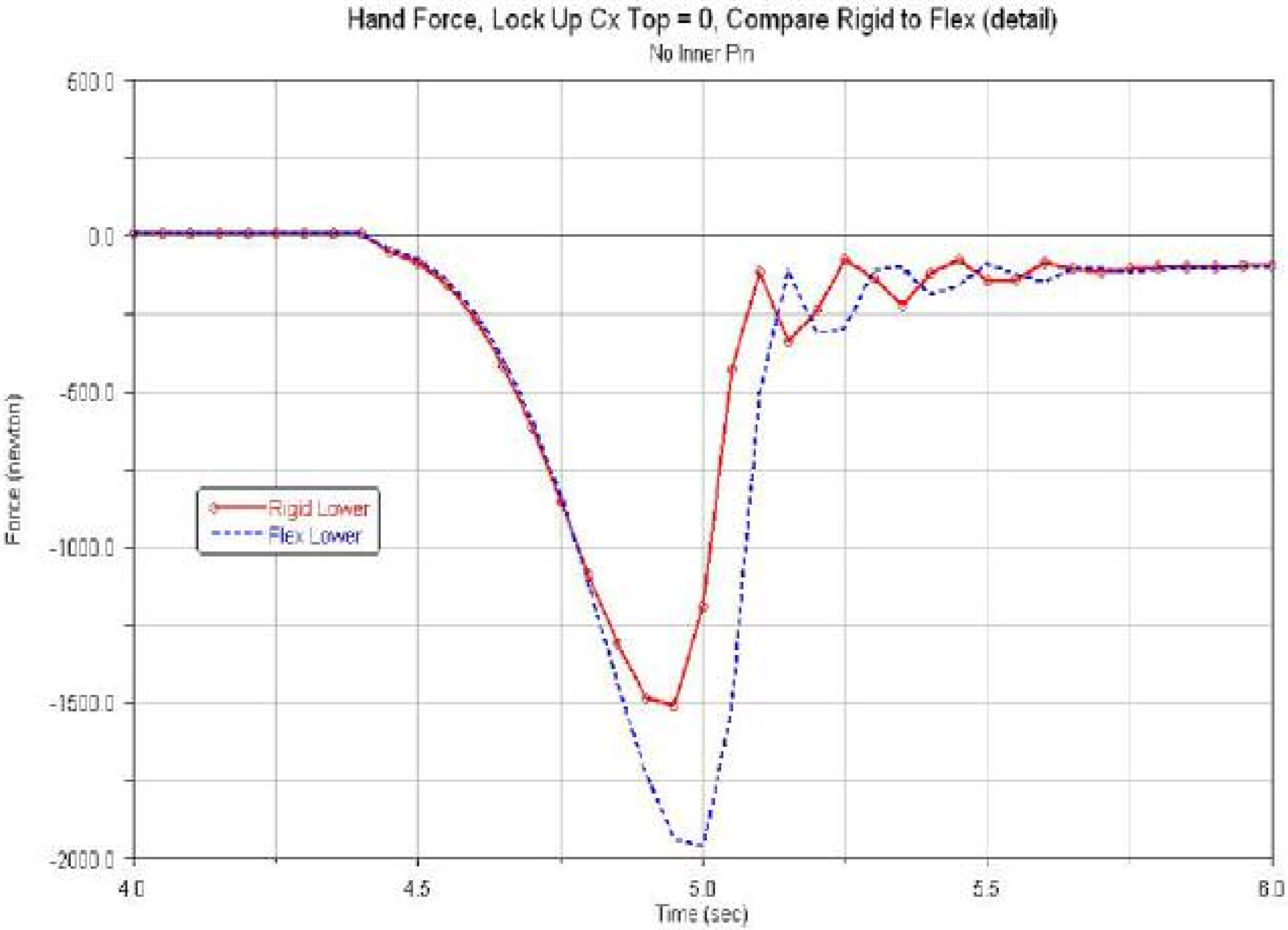
Torsion stiffness effect analysis





Hand Force Versus Cassette Angle, Effect of Flexibility and Plate Friction
All Pins Active
Flexible Lower, All Pins, Mu Plates 0.1
Rigid Lower, All Pins, Mu Plates 0.1
Flexible Lower, All Pins, Mu Plates 0.3
Flexible Lower, All Pins, Mu Plates 0.3, Pin Axial * 10
→ Better correlation Flex. Arm wrt measurements
Force (newton)
Angle (deg)
100.0
50.0
0.0
-50.0
-100.0
-150.0
-200.0
-250.0
0.0
3.0
6.0
9.0
12.0
15.0
18.0


Hand Force, Flexible Lower Versus Rigid, Mu Pin 0.35, Closing Force
100.0
50.0
0.0
-50.0
-100.0
-150.0
-200.0
-250.0
Force (newton)
Rigid, Mu Plates 0.10
Flex , Mu plates 0.30
Flex , Mu plates 0.10
Flex , Mu plates 0.30, Axial Stiff pins
0.0
1.0
2.0
3.0
4.0
5.0
6.0
7.0
8.0
9.0
10.0
Time (sec)

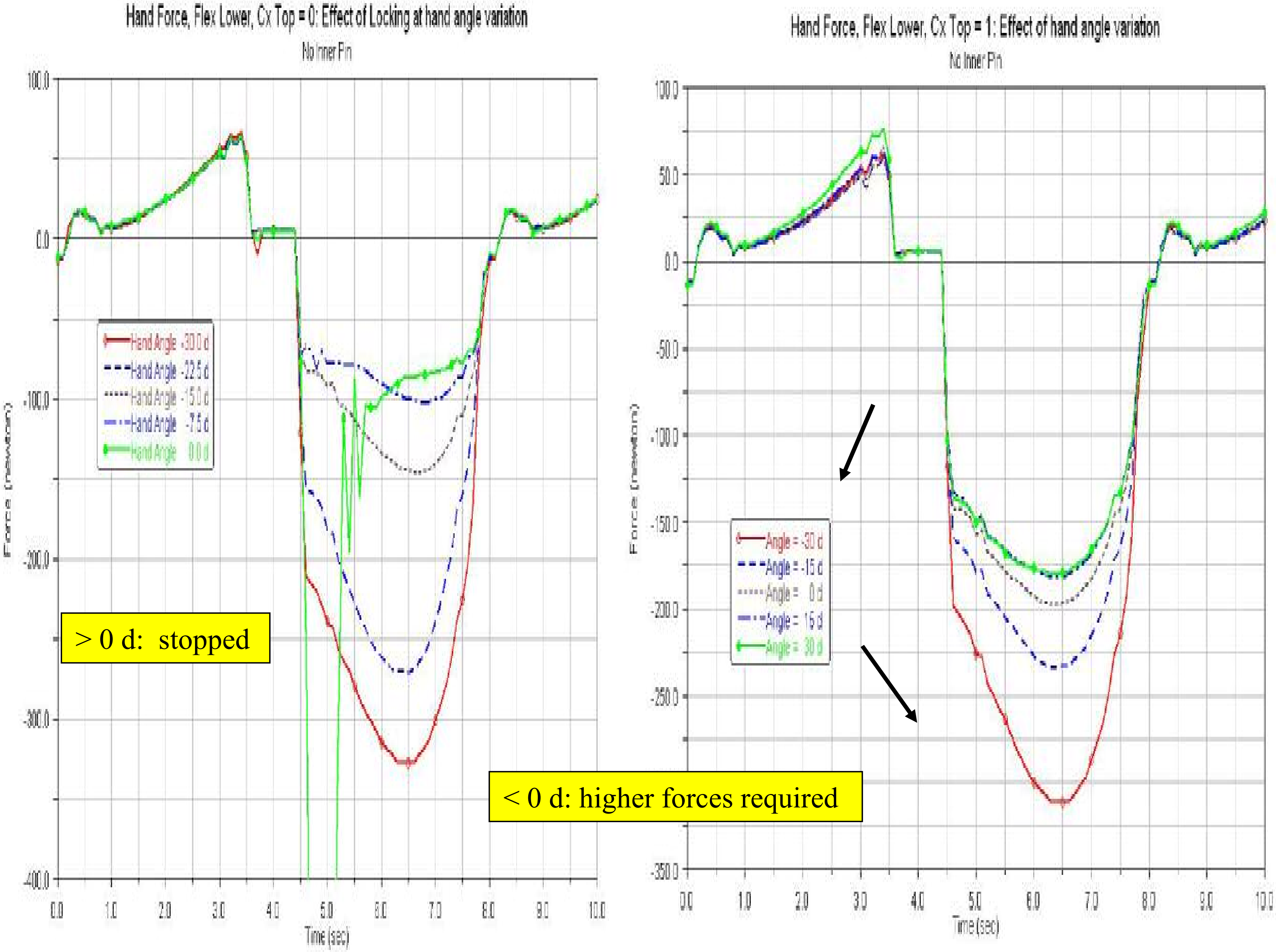


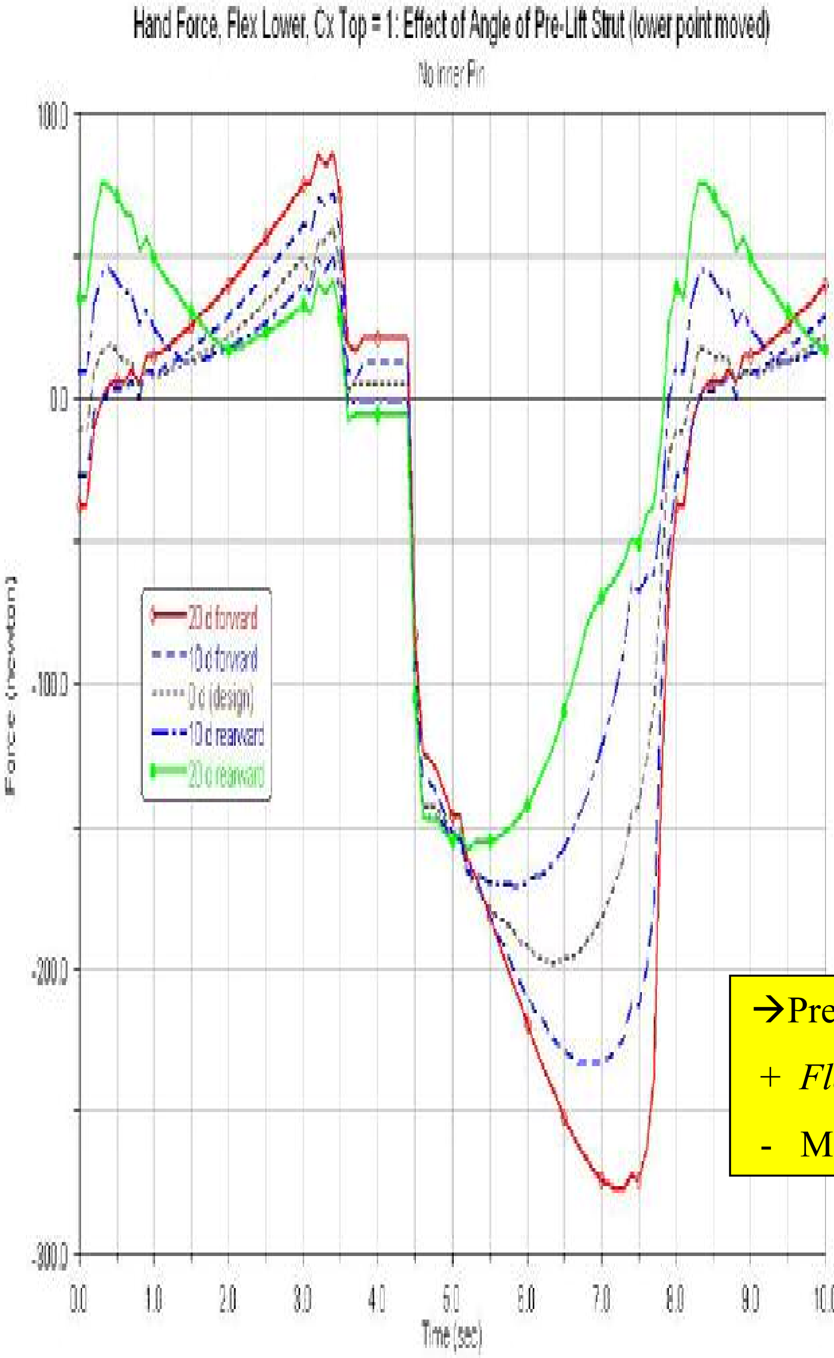
Hand Force, Lock Up Cx Top = 0, Compare Rigid to Flex (detail)
No Inner Pin
500.0
0.0
-500.0
-1000.0
-1500.0
-2000.0
Force (newton)
4.0
4.5
5.0
5.5
6.0
Time (sec)
Rigid Lower
Flex Lower

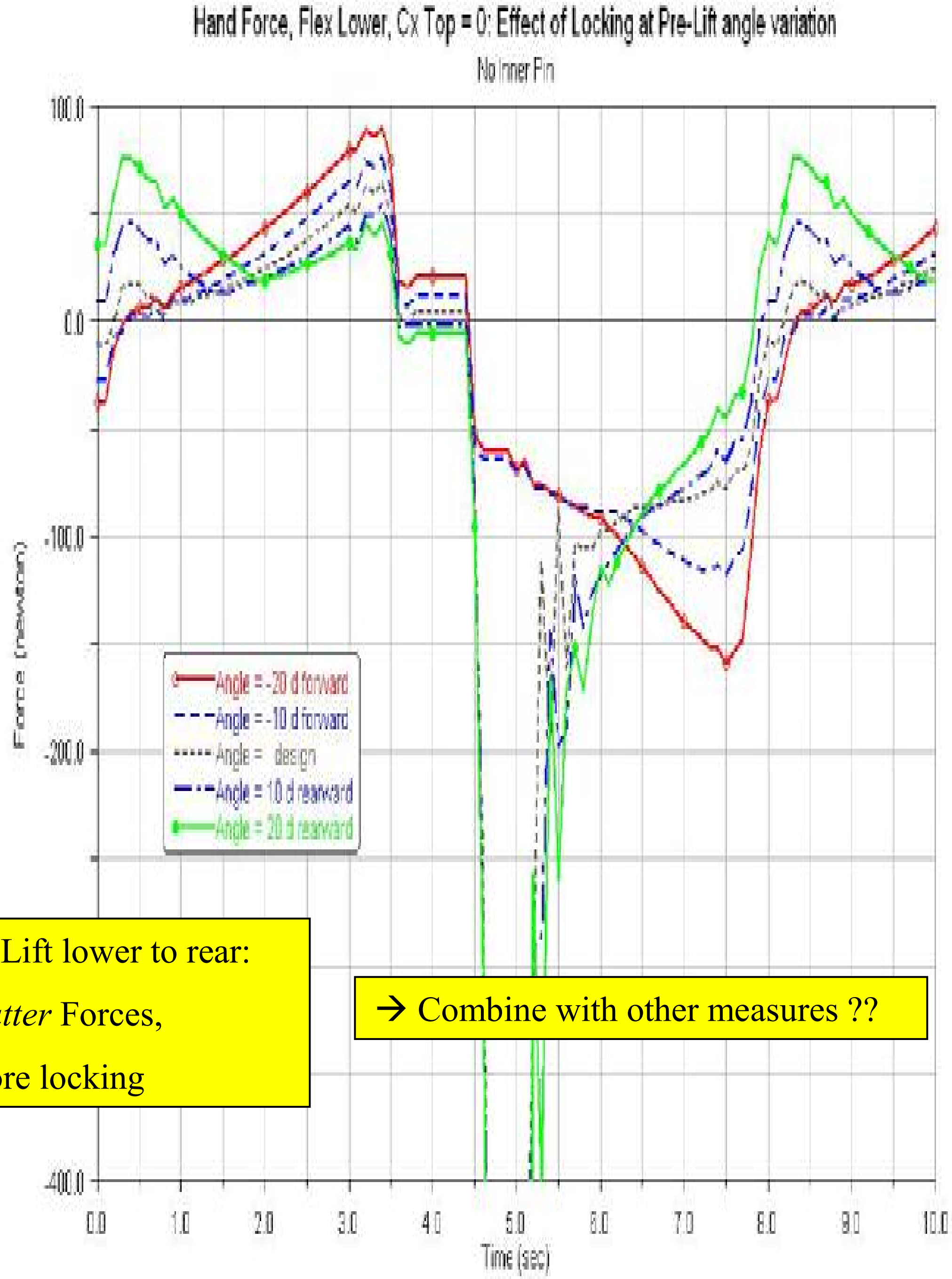
Parameter Study

Effects on locking & hand force

- Hand pushing angle: -30d +30d,
- Angle of Pre-Lift about top: -20d +20d,
- Centre Pin z-position lower: 0 - 50 mm,
- Angle Lower arm: 10 d – 20 d,


Hand Force, Flex Lower, Cx Top = 0: Effect of Locking at hand angle variation
No Inner Pin
Hand Angle -30.0 d
Hand Angle -22.5 d
Hand Angle -15.0 d
Hand Angle -7.5 d
Hand Angle 0.0 d
Force (newton)
Time (sec)
> 0 d: stopped
Hand Force, Flex Lower, Cx Top = 1: Effect of hand angle variation
No Inner Pin
Angle = -30 d
Angle = -15 d
Angle = 0 d
Angle = 15 d
Angle = 30 d
Force (newton)
Time (sec)
< 0 d: higher forces required



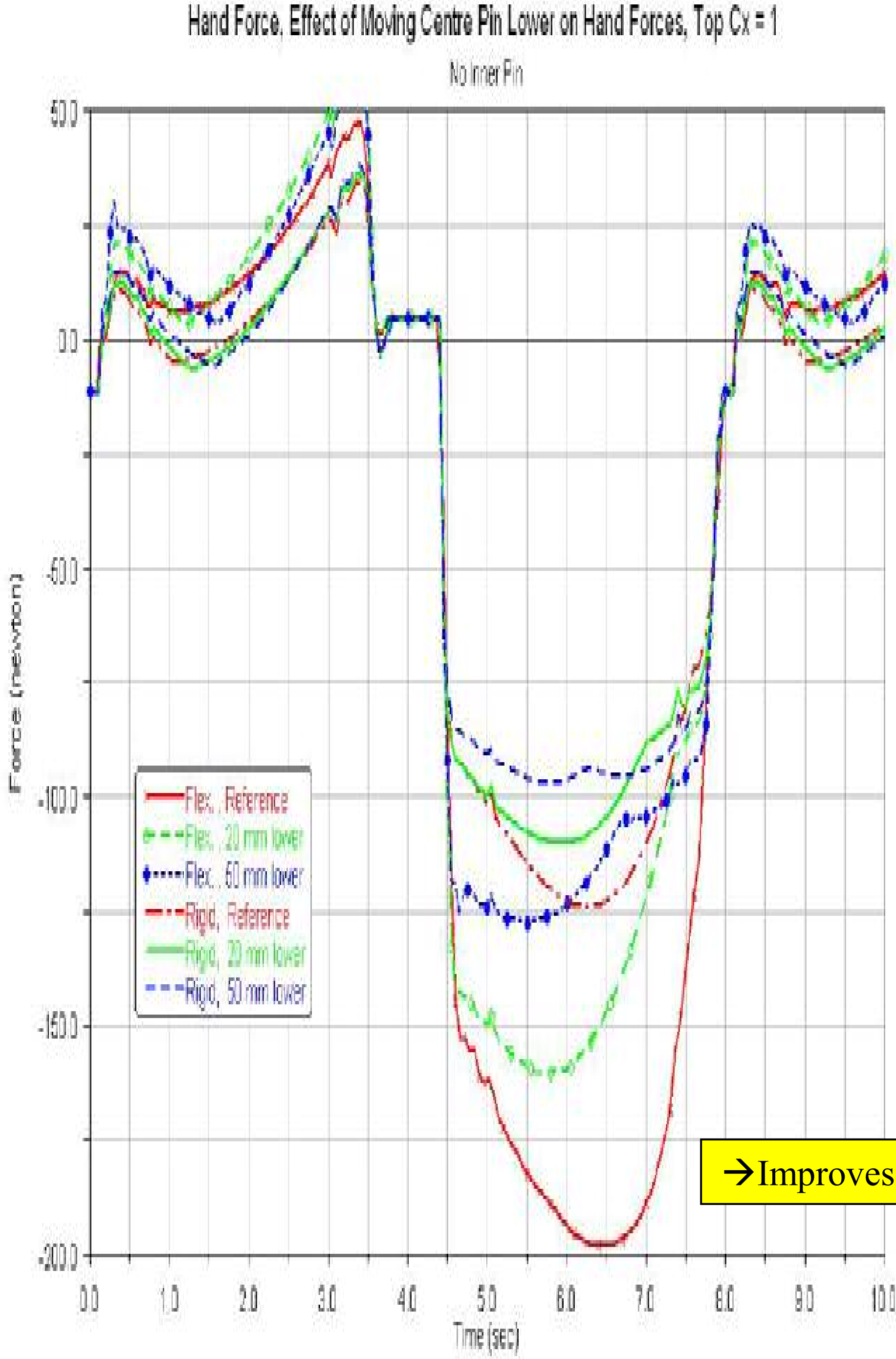


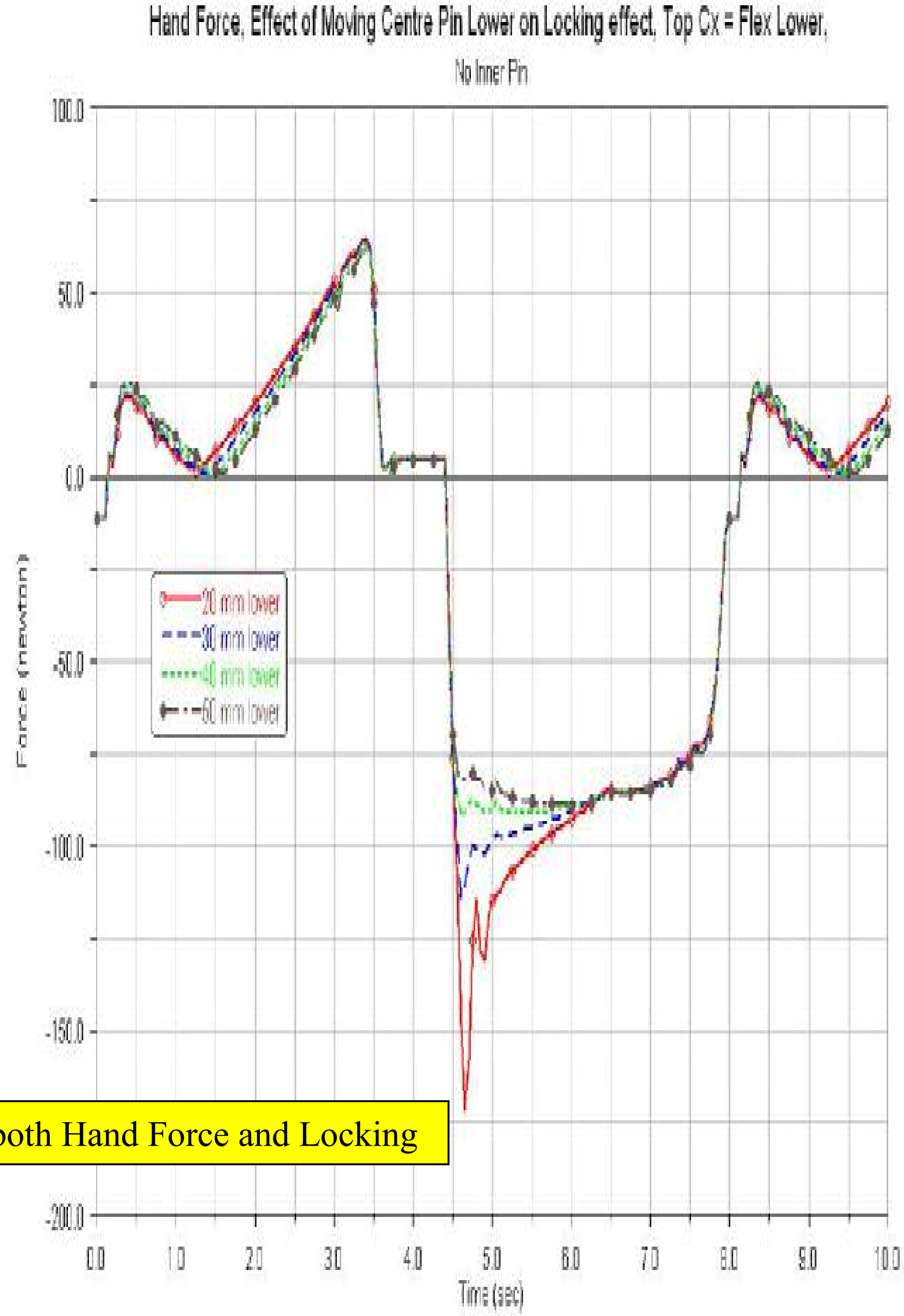
→Pre-Lift lower to rear:

+ *Flatter* Forces,

- More locking

→ Combine with other measures ??

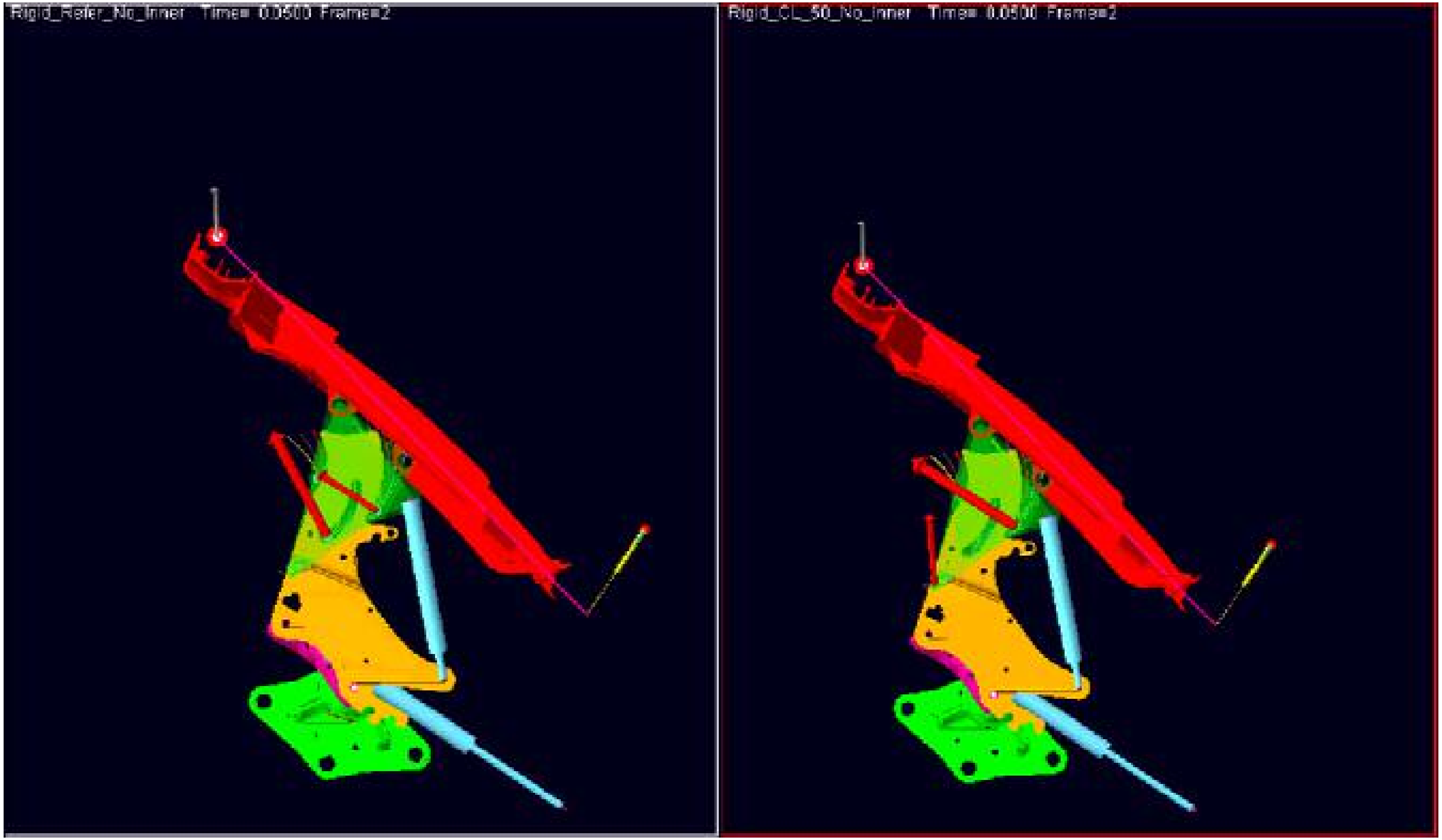


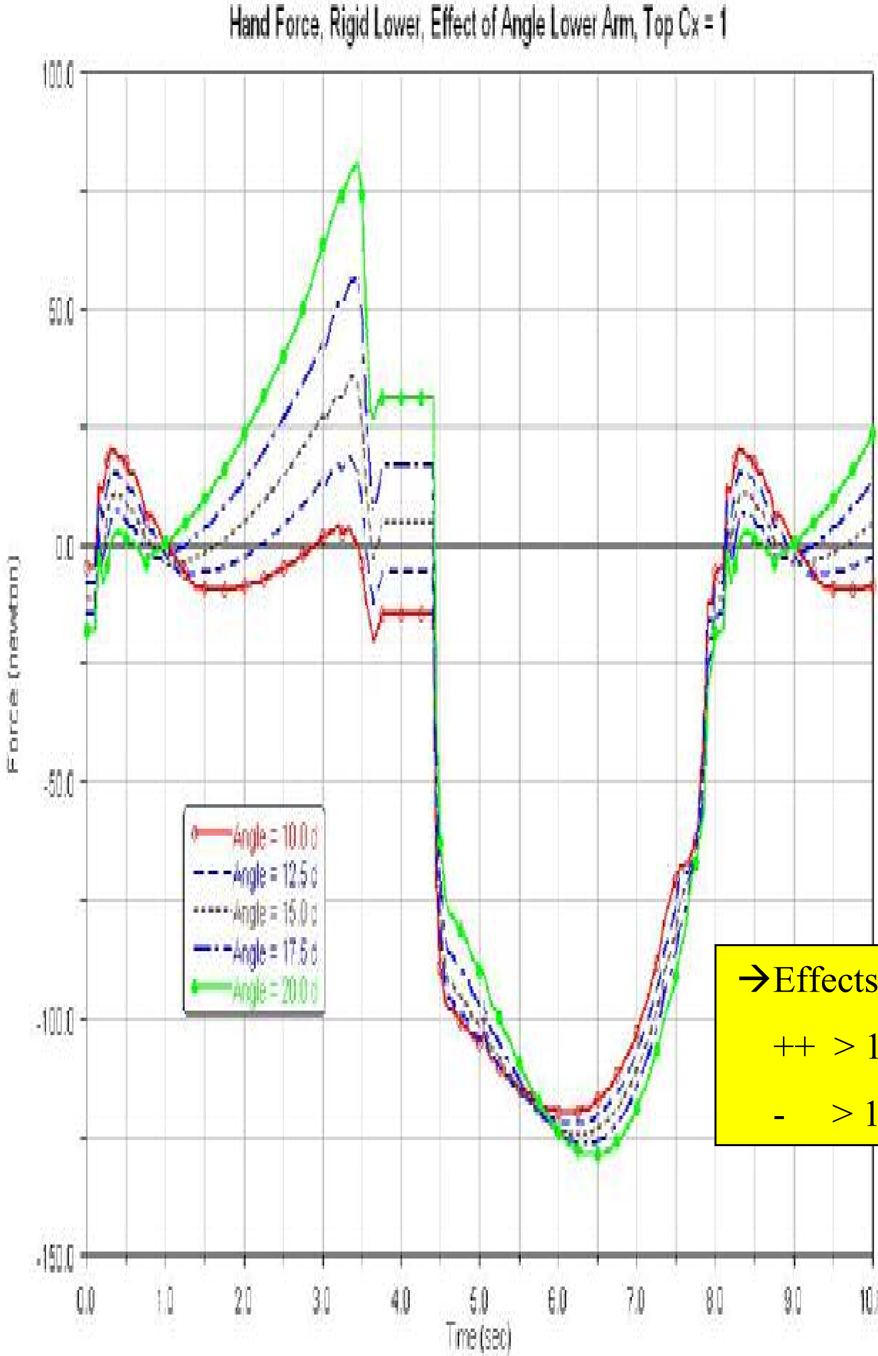


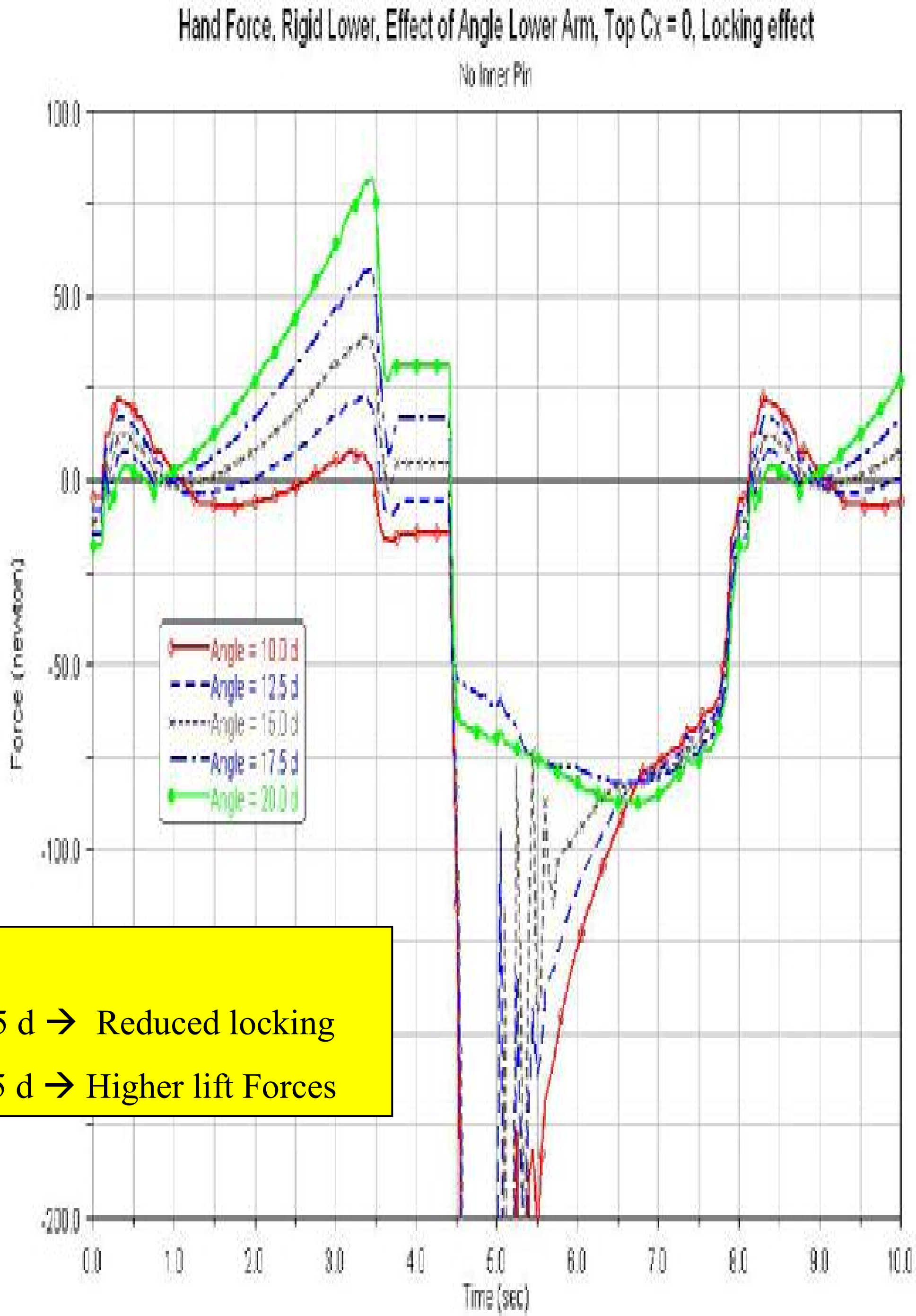
→Improves both Hand Force and Locking

Inner Pin: reference vs. 50 mm lower

Note the decrease in Hand Force and Upper Joint







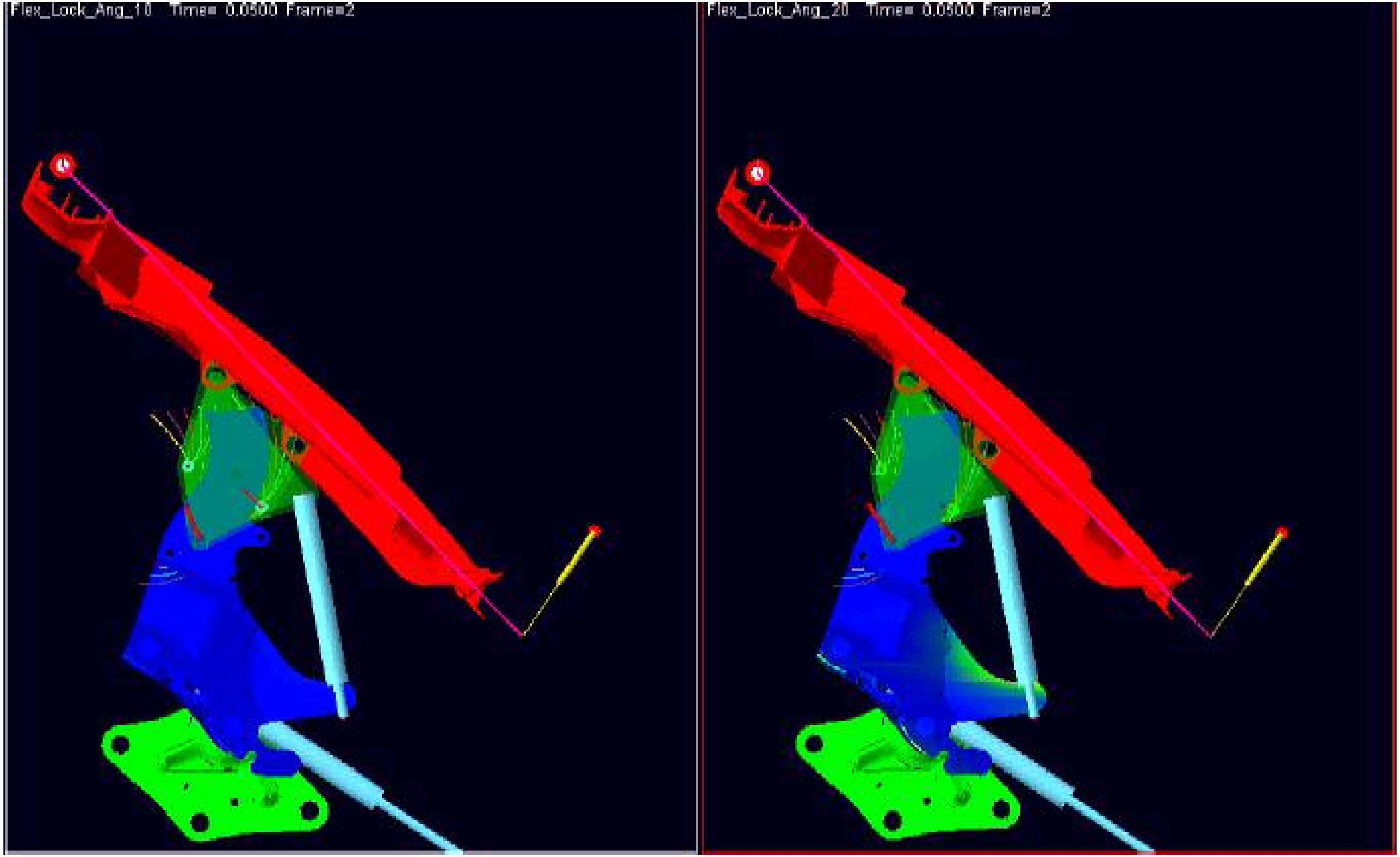
→Effects:

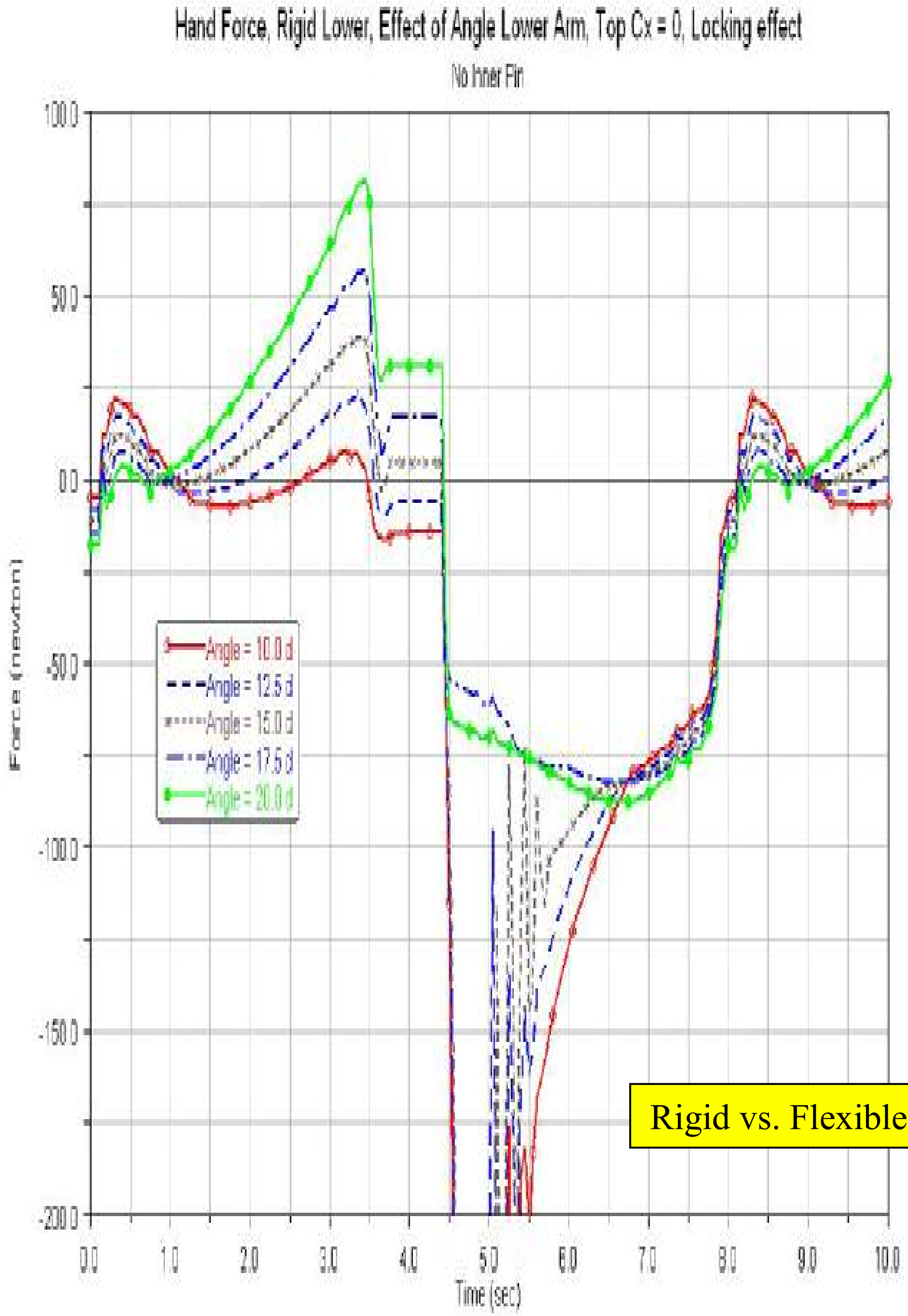
++ > 15 d → Reduced locking

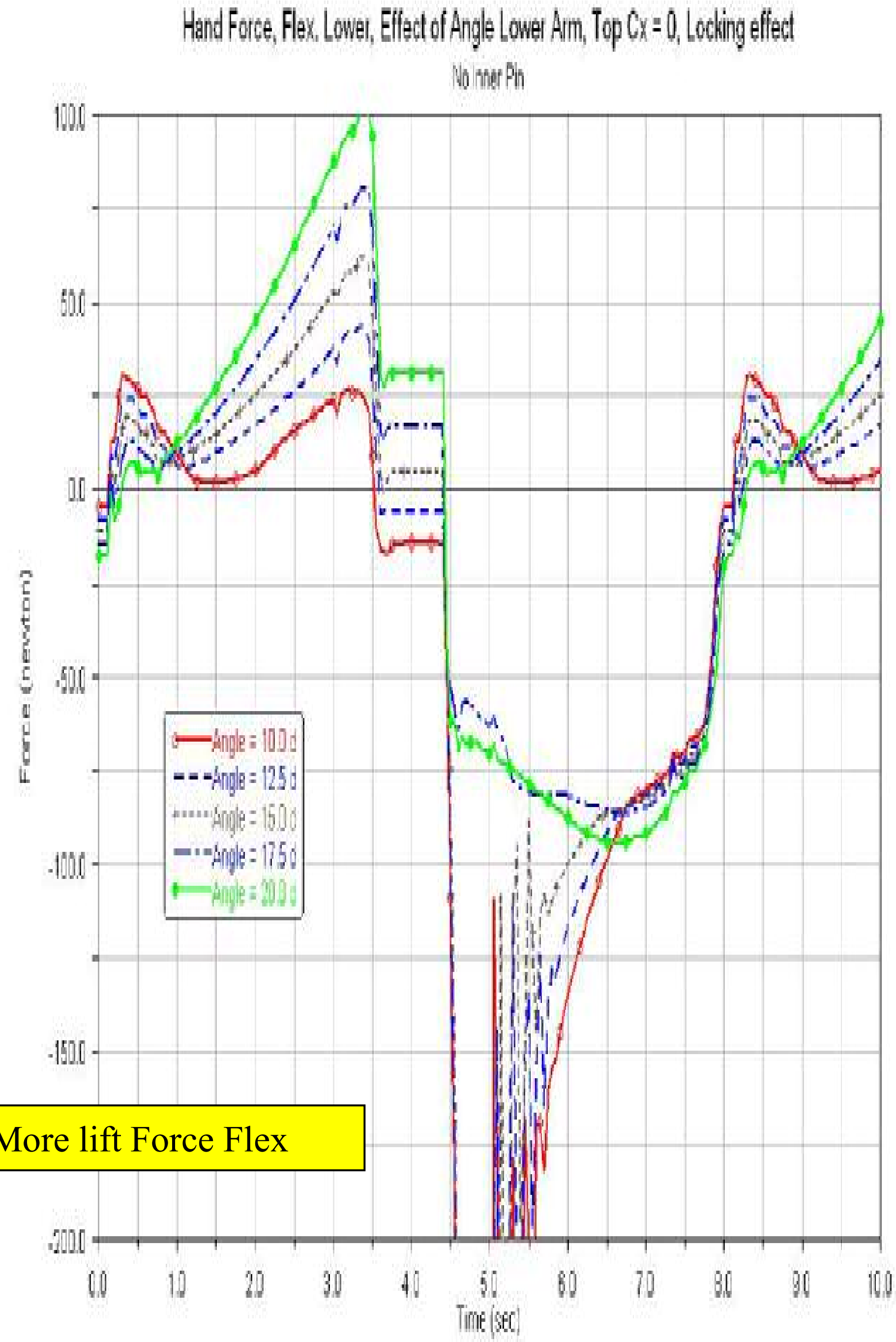
- > 15 d → Higher lift Forces

Lower Arm Angle: 10d vs 20d

Note the decreased locking effect







Rigid vs. Flexible: More lift Force Flex