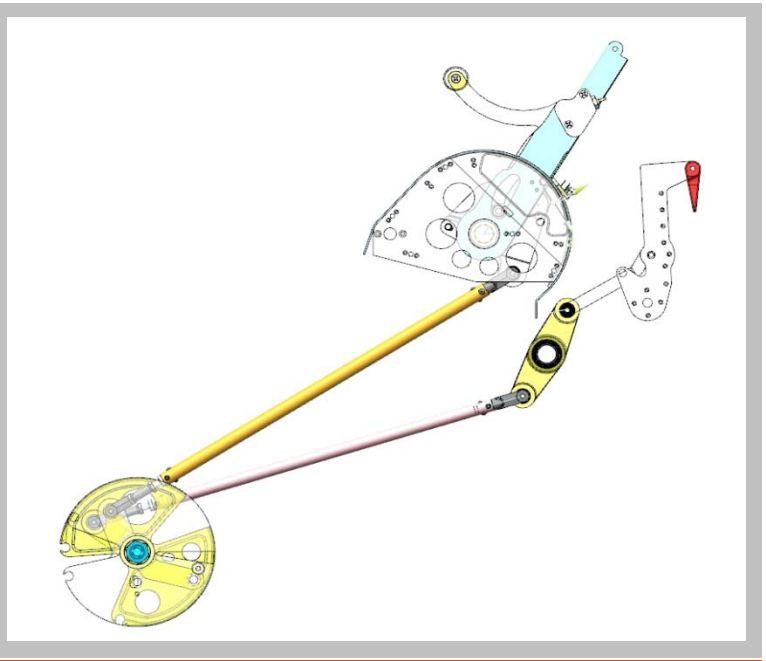
GIV Throttle and Gust Lock Kinematic Analysis



Date: July 24, 2015

Rockwell Collins

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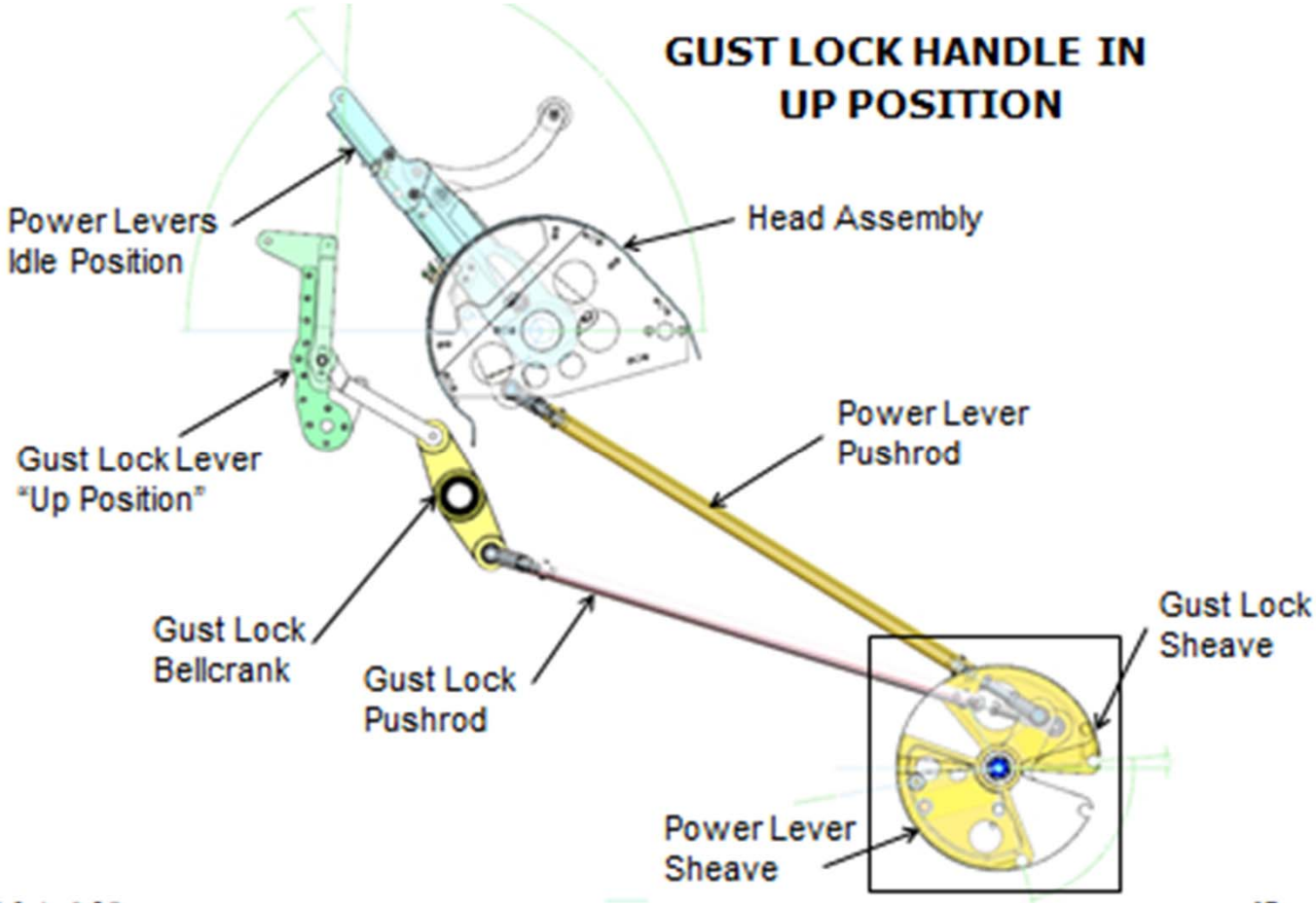
Overview

- Using modeling software, Rockwell Collins performed a kinematic analysis of the G-IV thrust lever assembly and gust lock lever assembly.
- The model was used to validate the amount of thrust lever travel when the gust lock lever is in the engaged “ON” position
- The model was used to determine the amount of additional thrust lever travel due to tolerances, backlash, and rigging
- The maximum throttle control authority was analyzed

Gust Lock / Throttle Lever Interlock



Throttle Control

Nominal Case

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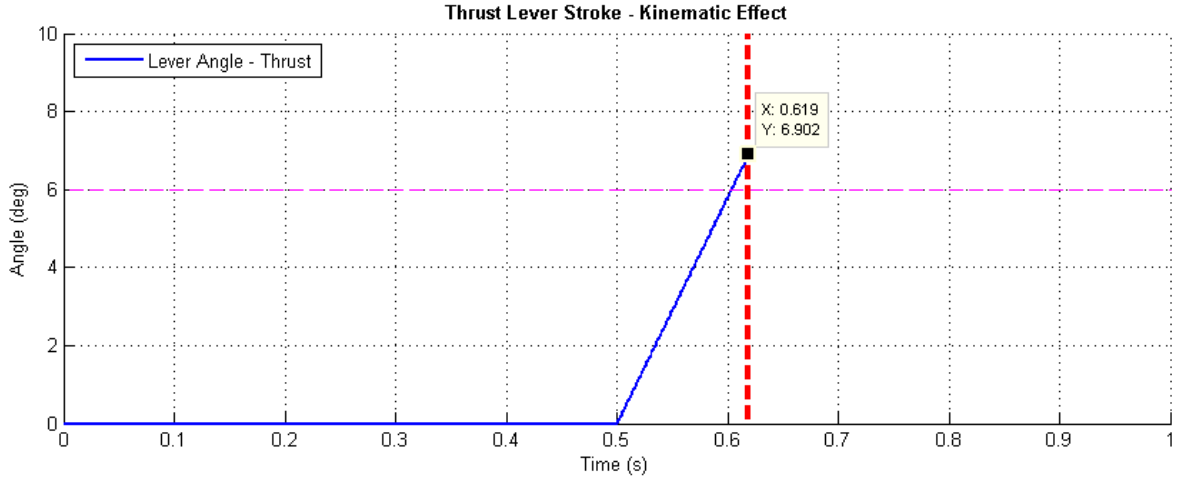
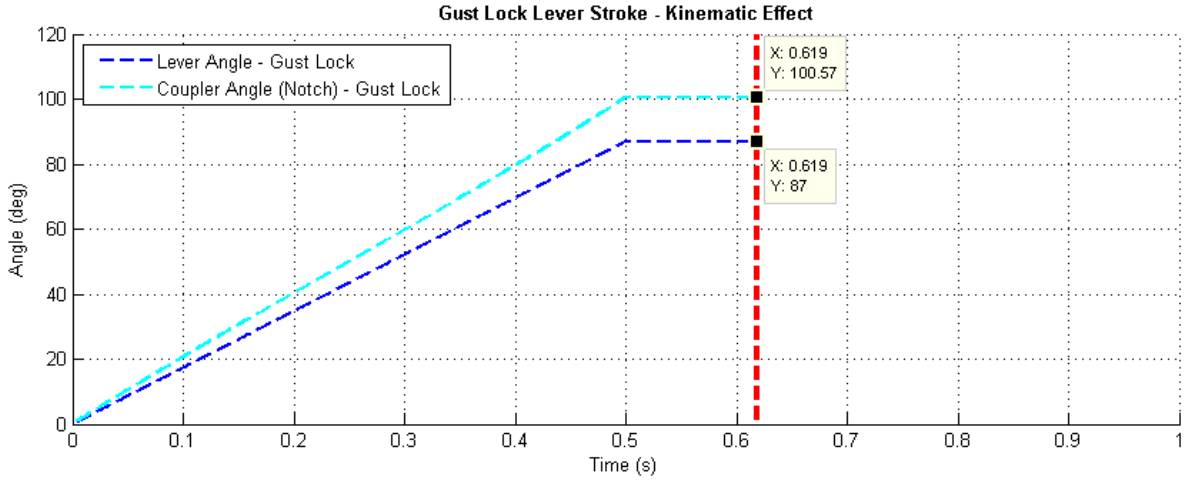
Simulation

- The motion of the gust lock linkage and the thrust linkage were simulated in the model.
  - Initial conditions of all joints are in nominal positions
    - Gust lock is in stowed, “Off” position
    - Throttle levers are in ideal rig pinned position
    - Control rods are adjusted to ideal lengths per above conditions
- First, the gust lock lever was moved throughout its range of motion (87° nominal) during the first half (0.5 sec) of the simulation.
- Then the thrust lever was moved through its range of motion until the thrust sector hub came into contact with the gust lock sector stop pin.
- After completion of the simulation, the variables of interest (thrust lever and sector angles, gust lock lever and sector angles, hub-to-pin distance, etc.) were analyzed and plotted.

Nominal Kinematic Results

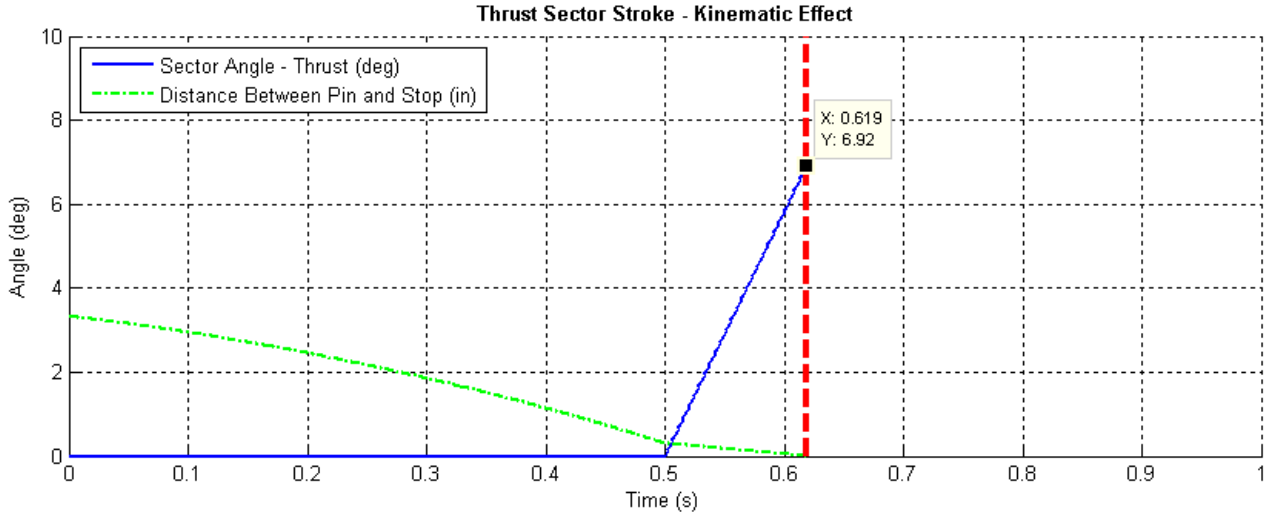
Thrust and Gust Lock Levers

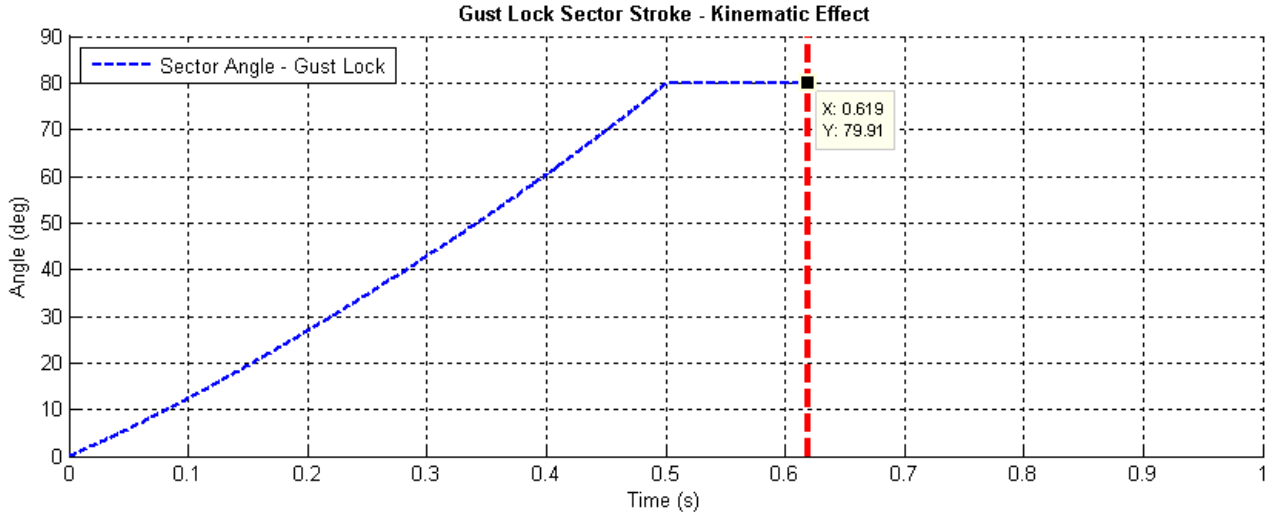




Nominal Kinematic Results

Thrust and Gust Lock Sectors





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Summary for Nominal Condition

Kinematics Element	Nominal Movement
Gust Lock Lever Angle	87°
Gust Lock Notch Angle	100.57°
Thrust Lever Angle to Interlock contact	6.902°
Gust Lock Sector Angle	79.91°
Thrust Sector Angle to Interlock Contact	6.92°

Throttle Control

Worst Case Manufacturing Variation,
Backlash, and Rigging

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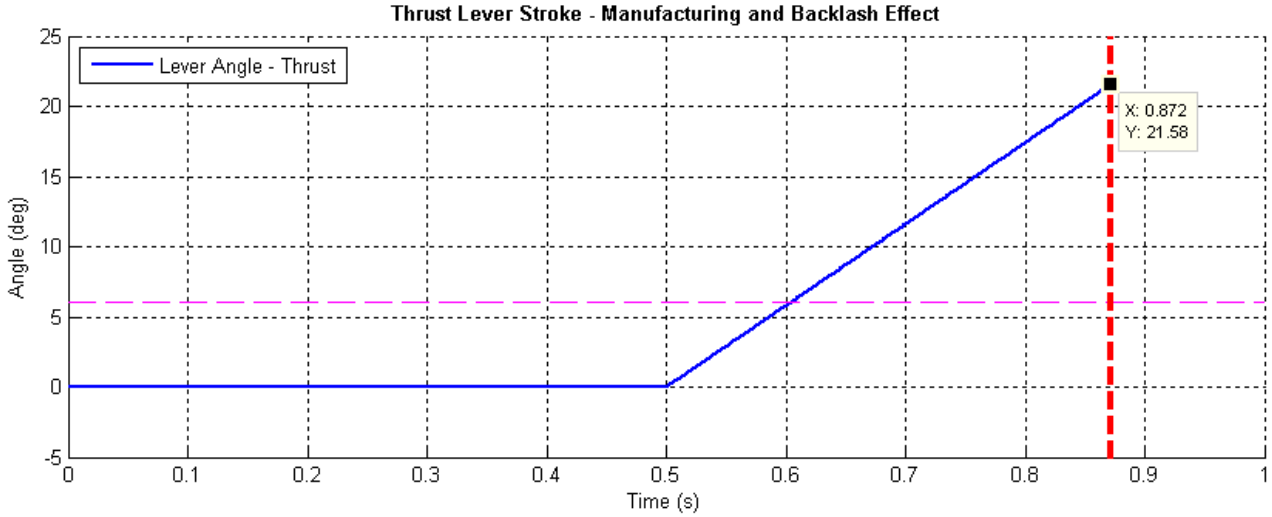
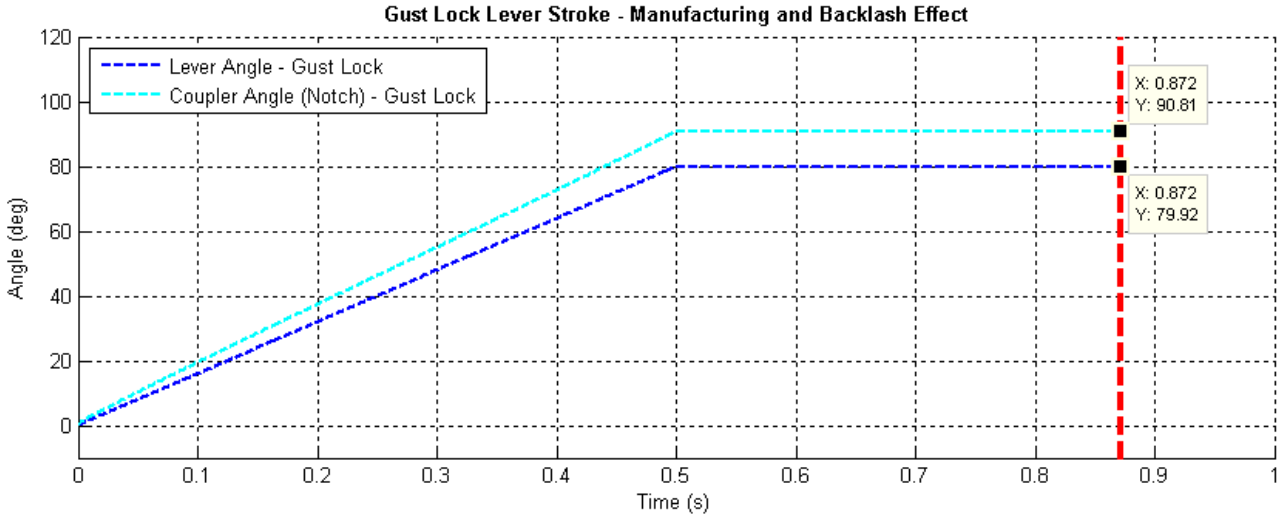
Tolerance Study

- The control rods can be adjusted to help account for initial tolerance effects due to manufacturing variation. The control rods are adjusted during assembly per the AMM requirements.
- Manufacturing tolerance can increase the amount of backlash within the mechanism. This backlash can effect the gust lock and thrust sectors rotation angles depending on the specific variation for a given rotation direction.
- For the purpose of this study, the manufacturing tolerance impact has been limited to those tolerances that maximize the backlash and resultant effect on the sector rotations
  - Maximize joint backlash values and tolerance effects
  - Assume control rod rigging does not eliminate any backlash effects
- The thrust and gust lock sectors were preloaded such that the limitation pins are separated from each other to maximize variation in the direction of increasing travel for the throttle levers
- The worst case position of the gust lock lever in the “ON” position including lock link slot backlash was considered.

Manufacturing and Backlash Results

Thrust and Gust Lock Levers





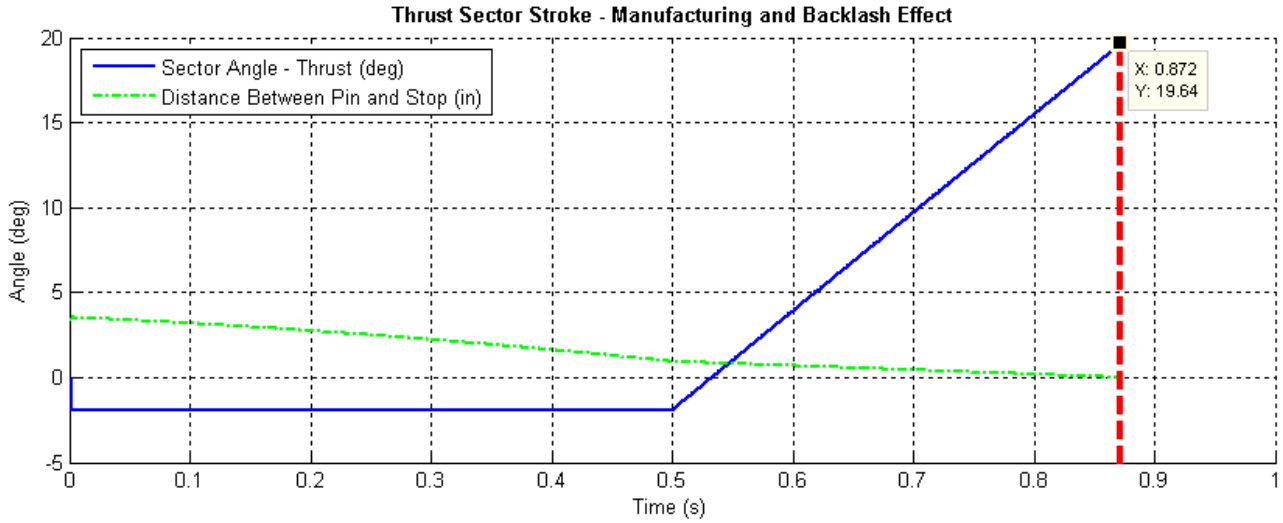
Worst Case Initial Sector Rigging Lash Contribution:
2 x 0.46° = 0.92°

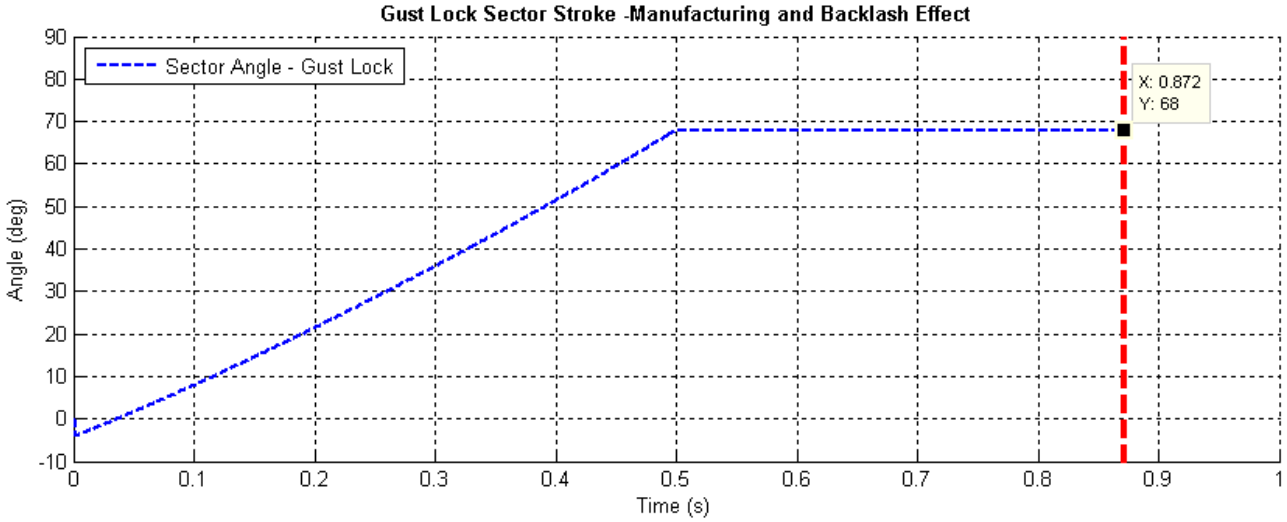
-5 Control Head Rigged as -4:
MAX THROTTLE LEVER STROKE:
21.58°+0.92°+3.2° = 26°

-5 Control Head Rigged as -5:
MAX THROTTLE LEVER STROKE:
21.58°+0.92° = 23°

Manufacturing and Backlash Results

Thrust and Gust Lock Sectors





Worst Case Initial Sector Rigging Lash Contribution:
2 x 0.46° = 0.92°

For Any Configuration:
MAX THROTTLE SECTOR STROKE:
19.64°+0.92° = 20.56°

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Summary for Worst Case Condition

Kinematics Element	Nominal Movement	With Manufacturing tolerance effects	Effect on Thrust Sector Angle due to manufacturing tolerances and initial sector rigging backlash effects - All configurations	Effect on Thrust Lever Angle due to manufacturing tolerances and -5 Rigged as -4	Effect on Thrust Lever Angle due to manufacturing tolerances and -5 Rigged as -5
Gust Lock Lever Angle	87°	79.92°			
Gust Lock Notch Angle	100.57°	90.81°			
Thrust Lever Angle to Interlock contact	6.902°	21.58°		26°	23°
Gust Lock Sector Angle	79.91°	68°			
Thrust Sector Angle to Interlock Contact	6.92°	19.64°	20.56°		

Conclusion

- Nominally, when the gust lock is engaged, the thrust lever and sector can travel about 6.9°.
  - No joint lash
  - No gust lock lever engagement mechanism lash
- Max throttle lever stroke when gust lock is engaged:
  - Worst case lash at each joint and engagement mechanism
  - -5 Control Head Rigged as -4: 26°
  - -5 Control Head Rigged as -5: 23°
- Max throttle sector stroke when gust lock is engaged:
  - Worst case lash at each joint and engagement mechanism: 20.6°

NOTE: The results of this analysis were cross-checked with the results of a separate Gulfstream analysis. Although the results were not exactly identical (Gulfstream calculations estimated the worst case throttle lever travel for a -5 control head rigged as a -5 control head to be approximately 23.8°), they are close enough that both parties accept the values given in this document as representative.