TECHNICAL MEMORANDUM

Project: Flight Dynamics Analysis of Cirrus SR22T
Date: October 7, 2024
To: Dr. Emmett Brown, Project Manager, Cirrus Aircraft Ltd
From: Graham Wilson

Summary

This memorandum presents the experimental simulation of three main flight dynamics parameters for the Cirrus SR22T aircraft using the REALSIMGEAR SRX AATD flight simulator. The primary objectives were to determine the aircraft's neutral point and characterize the natural frequency (ω_n) and damping ratio (ζ) of both the phugoid and short period modes. The experiments utilized various flight conditions and data analysis techniques to achieve these goals.

Methods

Neutral Point Determination

The neutral point was determined indirectly through measurement of elevator position relative to lift coefficient at different center of gravity (CG) configurations. The lift coefficient (CL) was calculated using:

$$C_L = \frac{L}{2\rho V^2 A} \quad [1]$$

where:
- L = aircraft weight (assumed equal to lift in steady flight)
- ρ = air density
- V = airspeed
- A = wing area

For each CG configuration, the relationship between elevator deflection δ and C_L was plotted, and the slope $\frac{\partial \delta}{\partial C_L}$ was determined. The neutral point is identified as the CG position where $\frac{\partial \delta}{\partial C_L} = 0$.

Dynamic Mode Analysis
Both phugoid and short period modes were analyzed using similar principles but different excitation methods. The damped natural frequency ω_d was determined from the period of oscillation:

$$\boldsymbol{\omega_d = \frac{2\pi}{T_{period}}} \quad [2]$$

The damping ratio was calculated using the logarithmic decrement method:

$$\boldsymbol{\zeta = \frac{\frac{1}{n-1} ln\left(\frac{t_2}{t_1}\right)}{\sqrt{4\pi^2 + \left[\frac{1}{n-1} ln\left(\frac{t_2}{t_1}\right)\right]^2}}} \quad [3]$$

where t_2 and t_1 are times at any two peaks in the oscillation, and n is the number of cycles between these peaks.

The undamped natural frequency was then calculated as:

$$\boldsymbol{\omega_n = \frac{\omega_d}{\sqrt{1-\zeta^2}}} \quad [4]$$

Procedures

Neutral Point Determination

1. Three CG configurations were selected:
  - Forward CG (near fore boundary)
  - Aft CG (near aft boundary)
  - Mid CG (between fore and aft)

2. For each configuration:
  - Aircraft was trimmed at steady altitude
  - Airspeed was varied by ±5 and ±10 [knots] while maintaining altitude
  - Elevator angle, airspeed, and altitude data were recorded

Phugoid Mode Analysis

1. Aircraft was trimmed at cruise condition
2. A pitch impulse input was applied until airspeed deviated 10-15 [knots] from trim
3. Controls were returned to neutral position

Short Period Mode Analysis

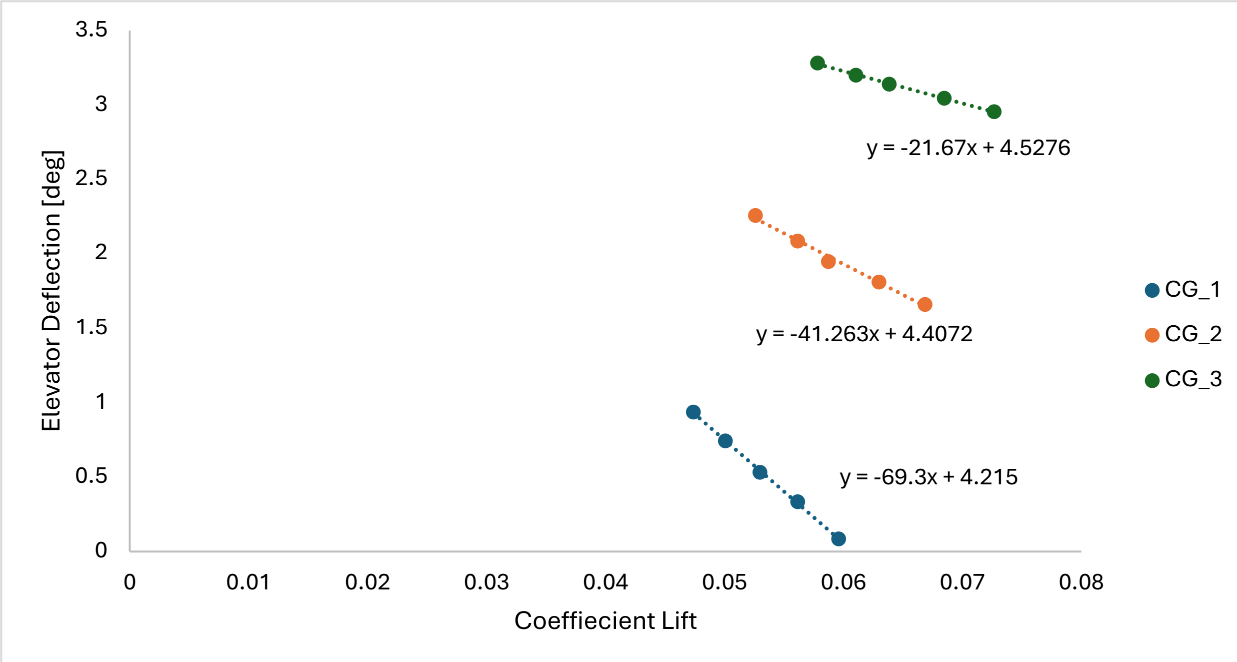
1. Aircraft was trimmed at cruise condition
2. A quick elevator doublet input was applied
3. Controls were immediately returned to neutral

Results

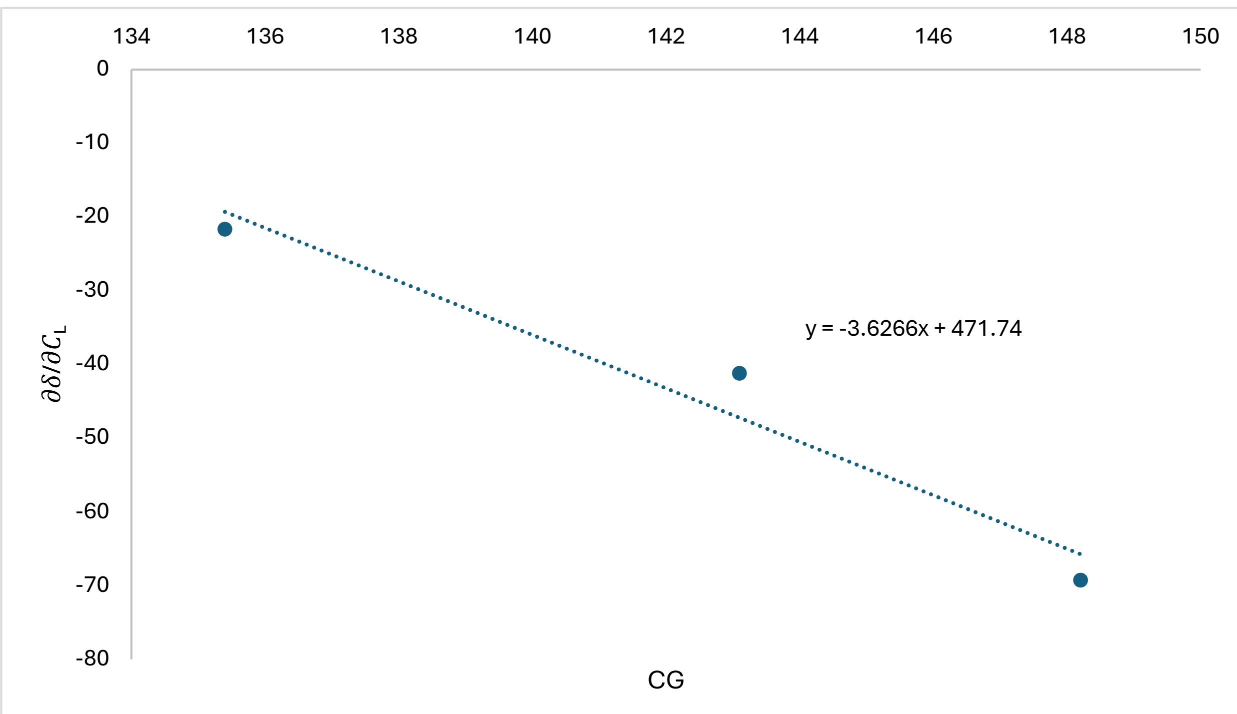
Neutral Point Analysis

CG	Weight (N)	Velocity (Knots)	Elevator Deflection [deg]	C_L
135.4	12549	185	0.935	0.0474
		180	0.742	0.05007
		175	0.534	0.05297
		170	0.336	0.05613
		165	0.083	0.05959
143.1	14079.8	186	2.256	0.05261
		180	2.087	0.05618
		176	1.95	0.05876
		170	1.81	0.06298
		165	1.662	0.06686
148.2	15303.55	185	3.28	0.0578
		180	3.2	0.06106
		176	3.14	0.06387
		170	3.046	0.06845
		165	2.954	0.07267

Values Written down During Test with Calculated Cl



Plot of Elevator Deflection vs Calculated Cl



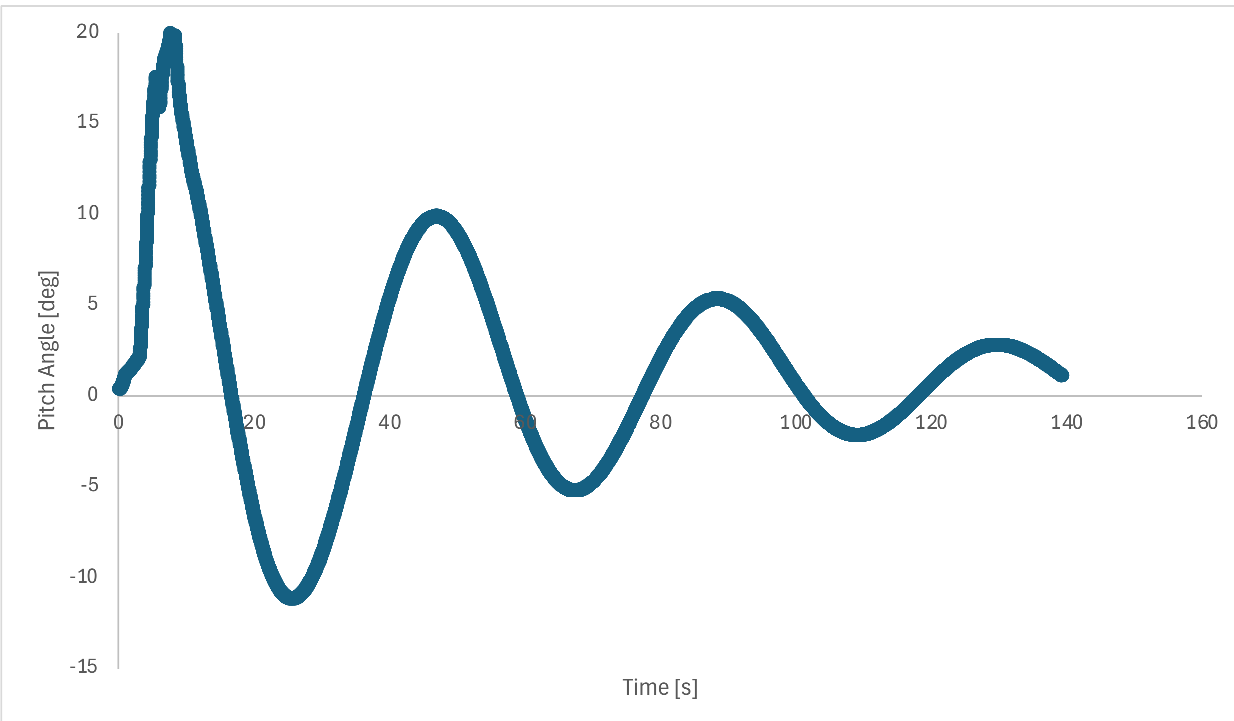
Plot of $\frac{\partial \delta}{\partial C_L}$ (slopes of graph above) **vs CG**

Using the slope and y-intercept, a value of 130.08 was found. $[\frac{471.74}{3.6266}]$, providing the neutral point location for this aircraft.

Dynamic Modes Analysis

Phugoid Mode

- Period: 41.6 seconds $[T_2 - T_2]$
- Damped natural frequency (ω_d): 0.151 rad/s [Eq. 2]
- Damping ratio (ζ): 0.09946 [Eq. 3]
- Undamped natural frequency (ω_n): 0.152 rad/s [Eq. 4]



Short Period Mode

- Period: XX seconds
- Damped natural frequency (ω_d): XX rad/s
- Damping ratio (ζ): XX
- Undamped natural frequency (ω_n): XX rad/s

plot of short period oscillations

Conclusions

The experimental analysis successfully provided critical flight dynamic parameters for the Cirrus SR22T aircraft. The neutral point, calculated at 130.1 units, is unexpected and less than expected. This may be due to an incorrect test for one of the CG's but this value is still relatively close to the expected ~142. The phugoid mode exhibited a low damping ratio, typical for such long-period oscillations and the slightly damped natural frequency confirmed the dynamic characteristics.

However, there were several potential sources of error that could affect the accuracy of the results:

1. **User input variability**: The manual input of control commands might have introduced inconsistencies, particularly during excitation for dynamic mode analysis.
2. **Limited CG configurations**: Testing only three CG positions limits the precision of the neutral point determination.

For future work, I recommend performing multiple runs for each configuration to statistically validate the results. Additionally, testing a broader range of CG positions could improve the accuracy of the neutral point determination.

References

1. Gregory, J. W., & Liu, T. (2021). Introduction to Flight Testing. Wiley.