Aerodynamic Efficiency Analysis - Skewness and Lift-to-Drag Ratio (Cl/Cd)

1. Introduction

The Lift-to-Drag Ratio (Cl/Cd) is a critical parameter in assessing aircraft performance, especially in different flight phases. Analyzing the skewness of Cl/Cd data provides insights into the asymmetry in the data distribution, which can impact the overall assessment of aerodynamic efficiency. This document explores the skewness of Cl/Cd ratios across various configurations and its implications.

2. Data Overview

The following table represents the filled data rows for the Cl/Cd ratio under specific conditions:

Run	Aircraft Type	Flight Phase	Angle of Attack	Speed	Cl/Cd
1	Conventional	Takeoff	0°	160 knots	2.00
2	Conventional	Takeoff	5°	150 knots	7.77
3	Conventional	Takeoff	10°	150 knots	7.02

3. Skewness Calculation

The skewness of the Cl/Cd data was calculated using the following steps:

Skewness Formula:

The skewness (S) of a dataset is calculated as:

$$S = \frac{n}{(n-1)(n-2)} \sum_{i=1}^{n} \left(\frac{x_i - \bar{x}}{s} \right)^3$$

Where:

- n is the number of data points.
- x_i is each individual data point.
- $\bar{x}$ is the mean of the data points.
- s is the standard deviation of the data points.

Skewness step by step calculation:

Step-by-Step Skewness Calculation

1. **Calculate the Mean ($\bar{x}$):**

$$\bar{x} = \frac{2.00 + 7.77 + 7.02}{3} = \frac{16.79}{3} = 5.5967$$

2. **Calculate the Standard Deviation (s):**

$$s = \sqrt{\frac{(2.00 - 5.5967)^2 + (7.77 - 5.5967)^2 + (7.02 - 5.5967)^2}{3 - 1}}$$

$$s = \sqrt{\frac{(12.931) + (4.712) + (2.033)}{2}} = \sqrt{\frac{19.676}{2}} = \sqrt{9.838} = 3.1367$$

3. **Calculate Skewness:**

For each value, calculate $\left(\frac{x_i - \bar{x}}{s}\right)^3$:

$$\text{For } x_1 = 2.00 : \left(\frac{2.00 - 5.5967}{3.1367}\right)^3 = \left(\frac{-3.5967}{3.1367}\right)^3 = (-1.147) \approx -1.51$$

$$\text{For } x_2 = 7.77 : \left(\frac{7.77 - 5.5967}{3.1367}\right)^3 = \left(\frac{2.1733}{3.1367}\right)^3 = (0.693) \approx 0.333$$

$$\text{For } x_3 = 7.02 : \left(\frac{7.02 - 5.5967}{3.1367}\right)^3 = \left(\frac{1.4233}{3.1367}\right)^3 = (0.454) \approx 0.093$$

$$S = \frac{3}{(3-1)(3-2)} \times ((-1.51) + (0.333) + (0.093)) = \frac{3}{2} \times (-1.084) \approx -1.626$$

Skewness Interpretation in Research

- **Negative Skewness (-1.626):** The data has a left skew, meaning that most of the data points are concentrated on the higher side (right side of the distribution) with a longer tail on the left. This suggests that while there are higher Cl/Cd ratios in most cases, there's a significant drop in Cl/Cd under certain conditions (like the first run).

4. Skewness Matrix

The following table summarizes the skewness values for each run:

Run	Cl/Cd	Skewness
1	2.00	-1.51
2	7.77	0.333
3	7.02	0.093
Overall Skewness		-1.626

5. Interpretation and Conclusion

The calculated skewness (-1.626) indicates a negative skew in the Cl/Cd distribution. This suggests that while most configurations yield high Cl/Cd ratios, certain conditions, such as those in Run 1, result in significantly lower values. This negative skew highlights the importance of carefully considering specific configurations and conditions when assessing overall aerodynamic efficiency.

The presence of lower-performing configurations is critical to understanding the full spectrum of aircraft behavior, particularly in diverse flight phases such as takeoff and cruise.