Fixed Trade Calculator – Application

Use of fixed trades to further an understanding of the impact of drag and its influence on whole aircraft attributes

Context

Fuel burn is the primary contributor to aircraft operating costs. Drag reduction is often discussed as a means of reducing both. Quantifying drag and its impact at a whole aircraft level can be difficult. Total aircraft drag includes among other things the effects of several types of drag (induced, pressure, trim, wave, interference, excrescence) as well as skin friction. Excrescence drag also includes the effects of discrete items (e.g. antennae and other externally mounted sensors), mismatches (steps and gaps), internal airflows and surface roughness.

As part of a published articles discussing the potential benefits of novel surface coatings to improve fuel burn the following statement is made:

“research has shown that surface coatings should not materially reduce drag, and that the most effective means of reducing drag is to maintain aerodynamically clean airplanes”[1] and that “unwashed airplanes can experience up to 0.1 percent increase in drag, poorer fuel mileage can be expected relative to clean airplanes” assuming 12% or wing reference area is contaminated (dirty).

The purpose of this application example is to illustrate the scale of the impact that small changes in drag can have at a whole aircraft level.

Using the Fixed Trade Calculator

The impact of 12% wing area contamination can be considered at the whole aircraft level using the ATI Fixed Trade Calculator.

Calculation choices:

- Aircraft type selection: Narrow (short haul) and Wide (long haul) body aircraft with technology levels representative of a year 2015 Entry into Service (EIS)[2] date.
- Flight definition: default flight range and utilisation options for each selected aircraft type
- Fuel Price[3] selection: 2.0 $/US Gal

Results:

		Narrow -body	Wide-body
Range	NM	750	3000
Utilisation	flights/year	1700	640
Inputs			
Changes in surface roughness – δDrag	%	0.1	0.1

[1] “Improving Airplane Environmental Performance”, Boeing AERO QUARTERLY Magazine, Issue 49, 2013, Quarter 1, pp 14-20
[2] ATI Fixed Trade Calculator Version # 1.3.1.1.1 and 1.4.1.1.1 used for this calculation
[3] Fuel price data is available from IATA average jet fuel price for 2019 (27/12/19) $1.98/Gal(US)

Outputs			
Increase in block fuel burn per flight	%	0.09	0.11
	kg	3	35
Increase in block fuel burn cost per aircraft per year	$	3,800	14,800
Increase in cash operating cost per year	%	0.02	0.04
Increase in CO_2 emitted per aircraft per year	kg	18,400	71,200

Discussion

This case demonstrates the importance that small changes in total drag can have at whole aircraft level. This might for an operator be a good starting point to establish whether it is cost effective to wash their aircraft and if so how frequently. However, in this case, the operating cost increase does not include the increased time on the ground that would be required to clean the plane and the cost of lost revenue associated with it, which would have to be considered as well.

For technology developers, this simple case could serve as a first approximation to quantify the potential value of a market for potential coatings technologies, since the report declares that the impact of cleaning the aircraft is more significant.

It is noticeable that the cost benefit of cleaning the wide body would be more significant than the narrow body aircraft (over three times). However, from this first calculation the cause of the difference cannot be identified. As currently set, the two aircraft models differ in range and utilisation and therefore time in the air, as well as cruising speed. Repeating both aircraft calculations with the same flight range and utilisation (2000NM and 850 flights/year) has the effect of increasing the impact on the narrow body but reducing that on the wide body as they now spend a similar time in the air. Though the impact on the wide body is still over twice the size (Fuel or CO_2) that on the narrow body.

Options for next steps following this analysis could include:

- Conducting a small parametric study using the Fixed Trade Calculator to understand the sensitivity of the results to fuel price. This could help turn the question into: “At what fuel price would it become cost effective to start cleaning the aircraft wings more frequently?”
- Conducting similar sensitivity analysis on the impact of flight range and utilisation. Considering “When scheduling cleaning, to maximise the benefit, which flights should cleaning be scheduled to immediately precede?”
- Turning the calculation around, to set operating targets. For example:

  In lieu of cleaning, there may be value in not carrying empty trolleys for the galley on an empty flight. What weight reduction would have the equivalent impact of aircraft fuel burn as cleaning the wing?