Specific Range Solutions Ltd.
"Your partner in flight optimization"
omer.majeed@srs.aero / 1.613.883.5045
www.srs.aero

A380 Flex Versus Max Take-Off Fuel Burn Analysis

This study was performed in response to a query from Vaisala Oyj, a company based in Finland specializing in airport weather measurement systems. The question was regarding the difference in fuel burn between Flex or reduced thrust take-off compared to maximum thrust take-off. For the purposes of this analysis, the Airbus A380-800 aircraft equipped with Rolls-Royce Trent 970-84 engines was chosen.

The only variable that was modified in the study was the throttle setting, all other aircraft parameters such as flap setting, air speeds and weight were unchanged, thereby enabling only the impact of thrust level on overall aircraft performance and fuel consumption to be assessed. Changing the take-off flap setting, the flap retraction point or the climb profile in any other way would impact lift and drag during take-off, hence the performance and fuel burn calculations.

Initial conditions for the analysis are as follows and based on an Aviation Week pilot report for the A380[1]:

- Sea level ISA conditions: Barometer 29.92 in. Hg / 0 ft ASL / 15 C
- Dry runway surface condition
- No wind
- Take-off weight = 859,000 lb (389,990 kg)
- Flex (75%) take-off thrust used = 210,000 lb (933 kN)
- Maximum take-off thrust available = 280,000 lb (1,244 kN)
- Flaps = Number 3 position
- V1 = 130 KIAS
- VR = 140 KIAS
- Vto_safety = 145 KIAS

Engine fuel flow was estimated using a third order polynomial equation derived from ICAO LTO (Landing & Take-Off) thrust and fuel flow data for the Trent 970-84[2]. Additional A380 technical data to create the take-off model were obtained from Jane's All the World's Aircraft[3]. The cumulative time, distance, altitude and fuel burn data are presented in Table 1 for the Flex (75%) and the Max take-off cases. The results were calculated using classical techniques for take-off analysis[4]. A schematic corresponding to the analysis points in Table 1 is presented in Figure 1.

Analysis Points	Total Time (sec)	Total Distance (ft)	Altitude (ft)	Total Fuel Burn (lb)	Delta Fuel Burn (lb)	Delta Fuel Burn (%)
Flex Take-Off (75%)						
1.1 Start of Ground Roll	0	0	0	0	0	0.0
1.2 Rotation	38	4,502	0	590	0	0.0
1.3 Lift-Off	41	5,213	0	637	0	0.0
1.4 End of Transition	43	5,714	44	669	0	0.0
1.5 Climb to 1,500 ft	77	13,972	1,500	1,190	0	0.0
Max Take-Off (100%)						
2.1 Start of Ground Roll	0	0	0	0	0	0.0
2.2 Rotation	28	3,272	0	597	7	1.1
2.3 Lift-Off	31	3,983	0	661	24	3.8
2.4 End of Transition	34	4,680	86	724	54	8.1
2.5 Climb to 1,500 ft	58	10,353	1,500	1,222	32	2.7

Table 1 – Cumulative Time, Distance, Altitude & Fuel Burn for A380-800 Flex vs. Max Take-Off (Sea Level ISA, No Wind)

Per the Aviation Week data[1], the time to rotate was 37 sec and the distance was 4,400 ft with 75% of maximum thrust, which are in good agreement with the time and distance at Point 1.2 in Table 1. The

[1] Aviation Week & Space Technology, October 2, 2006, A380 Pilot Report, pg. 48-51.
[2] Rolls-Royce Trent 970-84 data per ICAO_Engine_Emissions_Databank-Issue_16A (090204).xls
[3] Jane's All the World's Aircraft, IHS, 2009-2010.
[4] Aircraft Design: A Conceptual Approach, Daniel P. Raymer, AIAA Education Series, 1989.

© 2010 Specific Range Solutions Ltd.

time to the 35 ft obstacle height during the reported test flight was 43 sec and the distance close to 6,000 ft, which compares favourably with the calculated time, distance and height at Point 1.4, the end of the transition segment. The A380 take-off model at 75% of maximum thrust is therefore considered validated against the Aviation Week flight test data.

The Flex take-off case requires a total of 77 sec, 13,972 ft of horizontal distance and 1,190 lb of Jet A at sea level ISA conditions without wind to reach 1,500 ft of altitude above ground. The Max take-off case requires less time (58 sec) and horizontal distance (10,353 ft) to reach 1,500 ft AGL, but 32 lb (+2.7%) more fuel compared to the Flex case. Assuming an identical climb profile from 1,500 ft AGL to FL330 and acceleration to M0.82 for both cases, the aircraft using Max thrust take-off would then have to burn an additional 27 lb of Jet A to make up the difference in distance travelled, for a total of 59 lb of additional fuel burn to reach the same energy state i.e. altitude, distance traveled and air speed as the Flex case. The dynamic impact on fuel burn of moving to throttles to the Climb detent is ignored in both cases.

The cost difference for 59 lb of fuel would amount to $18.23 less for Flex take-off based on a refinery price of $2.056/U.S. Gal or $680.60/metric tonne of Jet A[5].

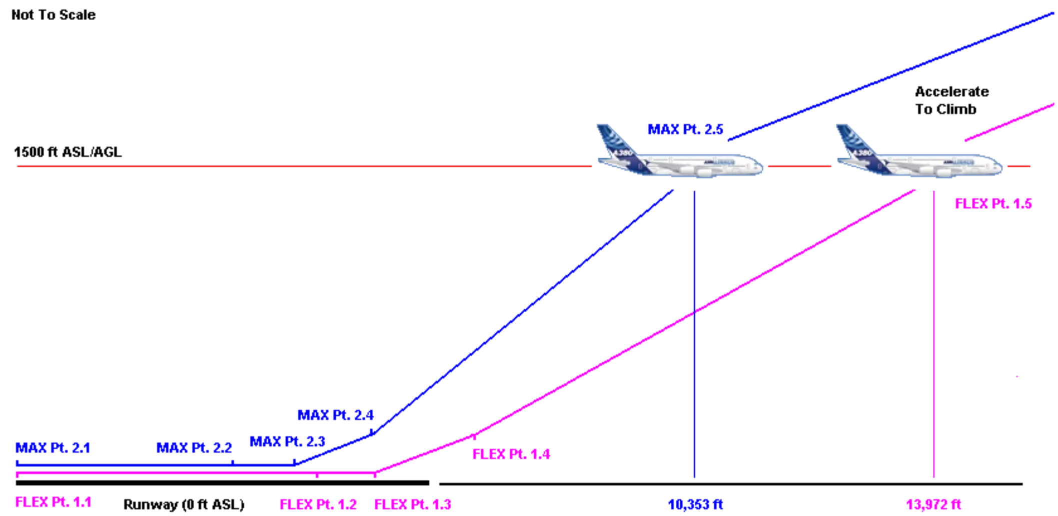

Figure 1 – Schematic of A380-800 Flex vs. Max Take-Off (Sea Level ISA, No Wind)

The difference in fuel burn between the Flex and Max take-off cases is relatively small and within the error margin of the calculations. However, it can be concluded that there is slightly reduced fuel burn using 75% take-off thrust compared to maximum thrust for the A380-800 under the prescribed conditions. A simulator session would be a useful check for this analysis. More generally, the precise impact on fuel burn of Flex take-off thrust will depend on the specific aircraft/engine combination, the thrust reduction level, engine condition, external temperature and pressure, etc.

The more significant benefit of Flex thrust take-off is the reduction in engine wear due to lower cycle temperatures, which has an associated benefit of reduced NO_X emissions[6]. The maintenance cost savings will be more significant than fuel cost savings as the high temperatures at Max take-off rating are the most damaging to an engine. Of course, nothing comes for free in the world of aviation governed by the laws of physics. The disadvantage of a reduced thrust take-off is performance-related, more runway length is required compared to maximum thrust take off (Point 1.3 versus 2.3) per Table 1, which impacts the balanced field length calculation.

Specific Range Solutions Ltd. has the capability to perform preliminary aircraft performance calculations and to assess the operational and cost impacts of modified procedures. Analysis of this nature can only be done in close cooperation with the client and by taking into account Aircraft Flight Manual (AFM), Standard Operating Procedures (SOP) and regulatory requirements. Any changes to procedures require a comprehensive risk assessment to ensure safety margins are maintained.

[5] IATA Jet Fuel Price Monitor Aug. 13, 2010, all prices quoted in U.S. dollars ($USD): http://www.iata.org/whatwedo/economics/fuel_monitor/Pages/index.aspx

[6] Operational Opportunities to Minimize Fuel Use and Reduce Emissions, IATA Circular 303, Feb. 2004.