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CFM56-7B24 SERIES AIRCRAFT ENGINE EMISSION MEASUREMENTS IN TESTCELL ENVIRONMENT and EMISSION INDEX DEVELOPMENT

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INTRODUCTION

- In this study, air pollutants, including nitrogen oxides(NOx, NO, NO_2), carbon monoxide (CO), carbon dioxide (CO2), and hydrocarbons(HC) from a newly overhauld CFM56-7B24 series turbofan engine measured in the test cell facility during engine functional test period at 27th December, 2013 at Turkish Technique Inc. in Istanbul, Turkey
- From the measured emissions, the Emission Indices for NOx, CO and THC were developped[1]
- The probe location was different then the other studies since the exit of engine nozzle was as close as possible to the outlet of the combustion chamber to avoid any dilution of exhaust gases with the by-pass air

METHOD

- Emissions were measured in a range of various power modes from idle to full thrust
- In a standard aproach-landing-taxi-taxi-takeoff cycle, which involves idle, low power and full-power operation
- N1(rpm), humidity(%), ambient air temperature(^oC), ambient air pressure(psi), fuel flow(kg/h), EGT(^oC), were available from engine test cell measurement system
- Emissions were measured from CFM56- 7B24 engine at 48.8 % humidity; 14.7 psi ambient air pressure and 12 ^oC ambient air temperature
- Emission indices were calculated in accordance witth ICAO emission index method
- Boeing Fuel Flow Method 2 was used to calculate the Air/fuel ratio(A/F):

$$F/A = \frac{\frac{[CO]}{10^4} + [CO_2] + \frac{[HC]}{10^4}}{207 - 2(\frac{[CO]}{10^4}) - CO_2}$$

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EXPERIMENTAL SETUP

Figure.1. Probe location in turbine nozzle

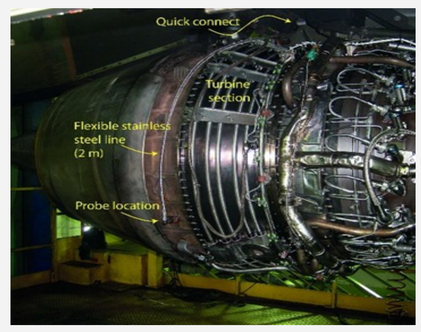


Figure. 2. Probe to sample line connections

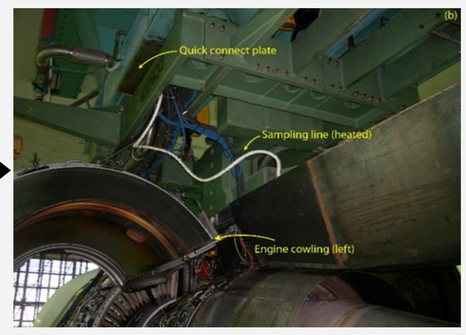


Figure. 3. Sample line to connect to analyzers

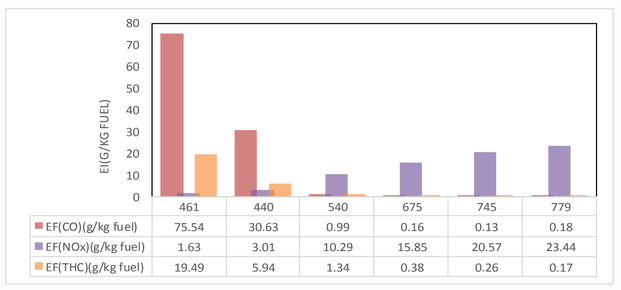
- The gaseous pollutants were determined by standard gas analysis. The sample system was in accordance with the ICAO requirements, concerning sample transfer times and line temperatures except for probe design and wet based NOx analysis
- The probe that was a single inlet modified from a temperature probe, and installed into the housing of the pressure probe located on the turbine frame, downstream of the last stage of the turbine rotor (Fig.1) .The orifice of the probe faced the exhaust flow.

RESULTS & DISCUSSION

Power Segments	N1 rpm	CO_2 (%)	CO (ppm)	HC (ppm)	NOx (ppm)	EI(CO) (g CO/kg fuel)	EI(HC) (g CH_4 / kg fuel)	EI(NOx) (g NO_2/ kg fuel)	A/F (air/fuel ratio)	FF(fuel flow) kg/s
21%	1016	2.22	872,3	392.9	11.4	75.5	19.5	1.6	87.1	0.920
Idle*						22.0	2.4	4.4		0.109
32%	1584	2.00	307.1	104.1	18.5	30.6	5.9	3.0	100.3	0.770
App*						2.2	0.1	10.1		0.316
67%	3291	2.77	13.5	32.1	86.5	1.0	1.3	10.3	73.7	6.085
Climb*						0.6	0.1	20.5		0.910
86%	4195	3.64	2.9	12.0	175.1	0.2	0.4	15.9	55.8	13.397
94%	4593	4.07	2.7	9.0	253.8	0.1	0.3	20.6	49.9	15.362
97%	4770	4.27	3.8	6.3	303.4	0.2	0.2	23.4	47.5	12.210
Takeoff*						0.4	0.1	25.3		1.103
32% (App.idle.cold)	1559	2.00	311.9	68.2	19.9	31.2	3.9	3.3	100.4	1.373
21% (Min.idle.cold)	1023	2.05	637.4	198.2	14.2	60.9	10.9	3.2	96.1	0.988

*** values from ICAO emissions database[2]**

Tablo.1. Emissions and emission indices from CFM56- 7B-24 engine at 48.8 % humidity; 14.7 psi ambient air pressure and 12 ^oC ambient air temperature



EF(CO)(g/kg fuel)	75.54	30.63	0.99	0.16	0.13	0.18
EF(NOx)(g/kg fuel)	1.63	3.01	10.29	15.85	20.57	23.44
EF(THC)(g/kg fuel)	19.49	5.94	1.34	0.38	0.26	0.17

Figure 4. Emission indices of three exhaust species at Exhaust gas temparatures(EGT,^oT)

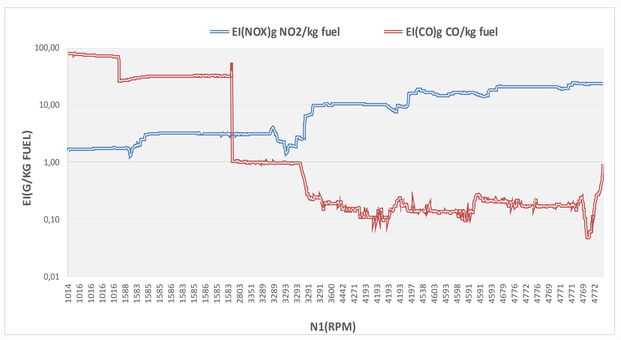


Figure 5. Emission indices of CO and NOx at N1 power settings

CONCLUSION

- Nitrogen oxides were produced at high engine power settings and with increasing power the NOx emissions increased. NOx emission index had the highest value at in minimum idle thrust.
- Hydrocarbons decreased with increasing power, at minimum thrust(%21) (power settings referred to as minimum idle), HCs were maximum concentrations. Emission index of HC was the highest at minimum idle thrust.
- CO emissions increased with decreasing power settings, CO Emission indices were the highest value at in minimum idle thrust.
- ICAO values tend to be higher (or closer) compared to the current study's CO and THC Emission Indices results from ICAO Data Base. NOx emission values are close values to ICAO NOx EIs[2]

REFERENCES

[1] ICAO Annex 16 Environmental Protection, Volume II Aircraft Engine Emissions

[2] ICAO Emission Databank: https://easa.europa.eu/document-library/icao-aircraft-engine-emissions-databank

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