TURBOJET ENGINE CYCLE OPTIMIZATION

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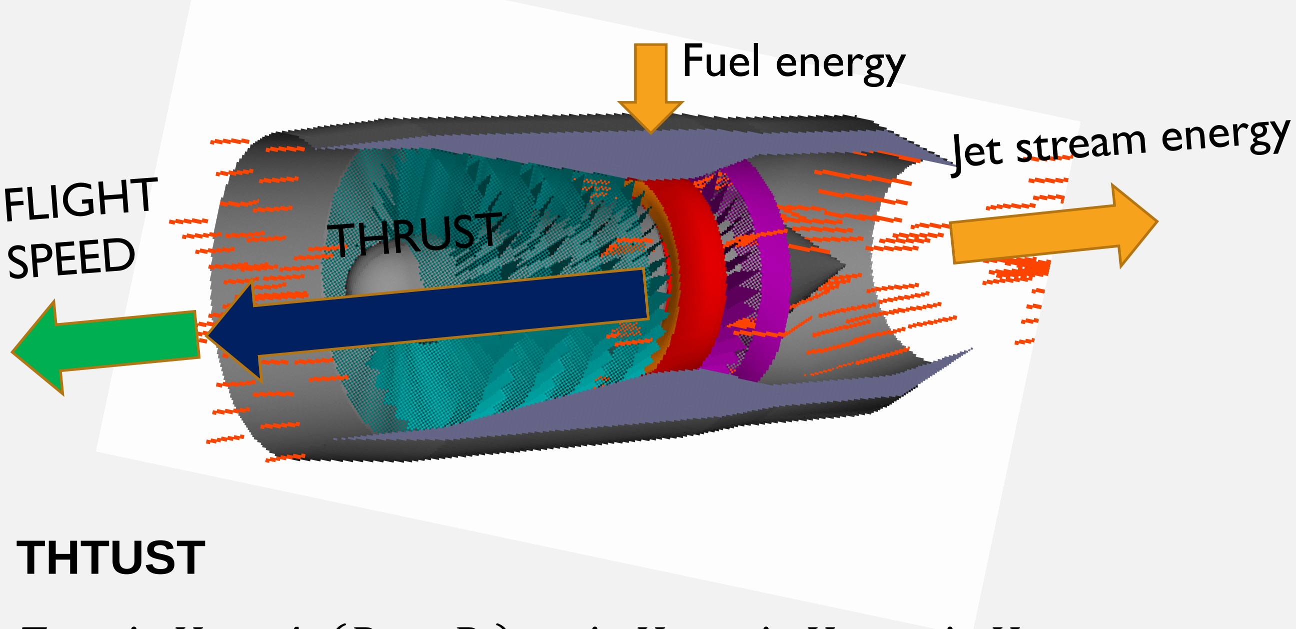
LITERATURE:

- **Jack D. Mattingly, Elements of Propulsion: Gas Turbines and Rockets, AIAA Education Series 2006 (Chapter 7)**
- **Jack D. Mattingly, Elements of Gas Turbine Propulsion, Tata McGraw Hill Education Private Limited, 2013 (Chapter 7)**
- **Gordon C. Oates, Aerothermodynamics of Gas Turbine and Rocket Propulsion, AIAA Education Series, 1997 (Chapter 7)**

ENGINE EFFICIENCIES



Thermal efficency

$$\eta_{TH} = \frac{0,5 * (\dot{m}_9 {V_{9e}}^2 - \dot{m}_0 {V_0}^2)}{\dot{m}_f FHV}$$

Propulsive efficency

$$\eta_P = \frac{V_0 * T}{0,5 * (\dot{m}_9 {V_{9e}}^2 - \dot{m}_0 {V_0}^2)}$$

Overall efficency

$$\eta_O = \eta_{TH} * \eta_P = \frac{V_0 * T}{\dot{m}_f FHV}$$

THTUST

$$T = \dot{m}_9 V_9 + A_9(P_9 - P_a) - \dot{m}_0 V_0 = \dot{m}_9 V_{9e} - \dot{m}_0 V_0$$

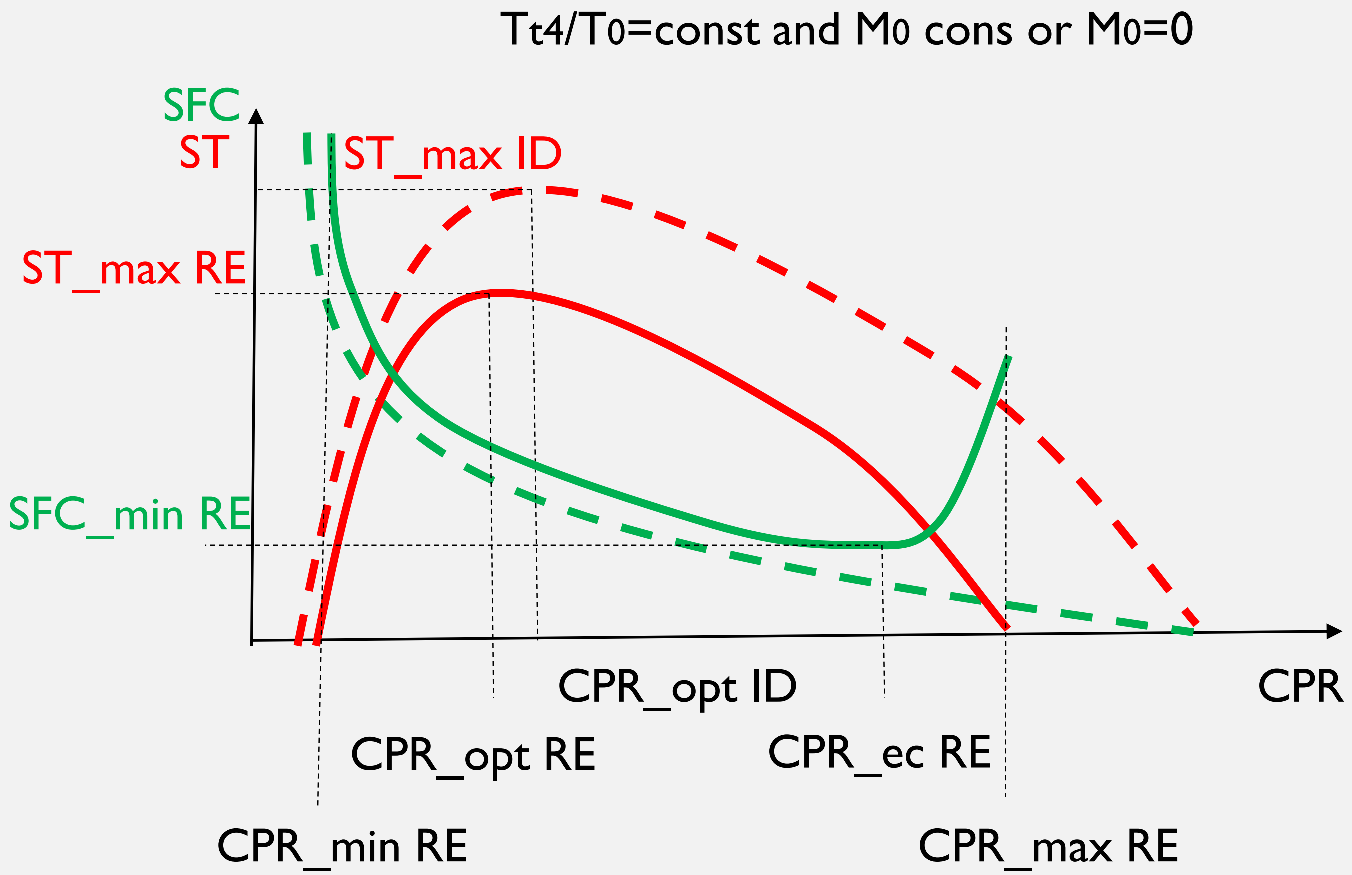
SPECIFIC THRUST

$$ST = T/\dot{m}_0$$

SPECIFIC FUEL CONSUMPTION

$$\mathrm{SFC} = \dot{m}_f/T$$

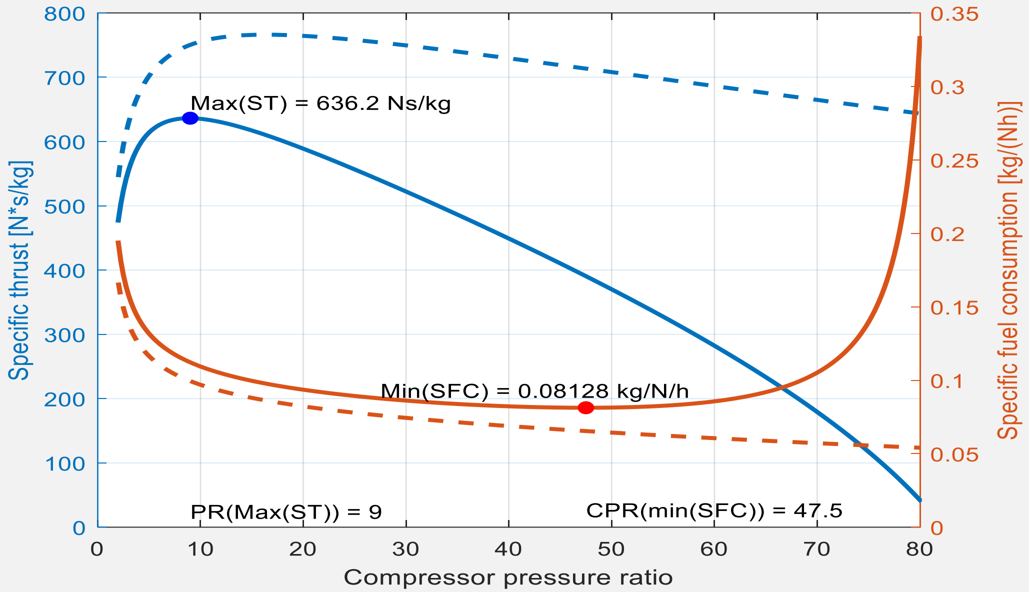
TURBOJET CYCLE OPTIMISATION REAL VS IDEAL

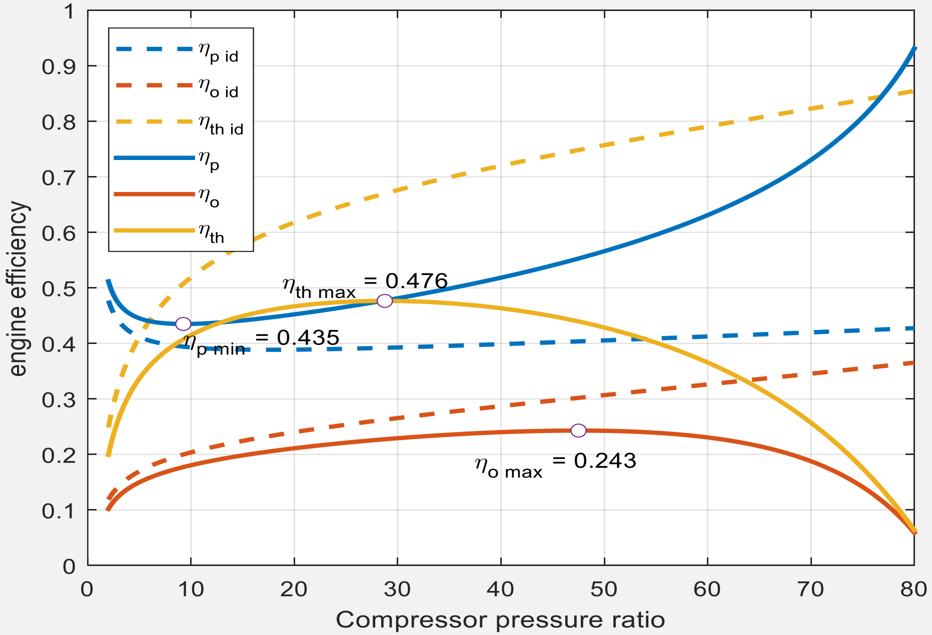


SUMMARY:

- Specific thrust (ST) of real engine looks similar to ideal engine. It grows with compressor pressure ratio, achieves maximum for optimal CPR than is goes down. Differences:
  - ST is lower in whole range of CPR than in an ideal engine
  - Pressure ratio of ST_max is lower than in ideal engine
- Specific fuel consumption (SFC) is higher than in ideal engine. It decreases with CPR growth, achieves minimum value for high CPR and then goes up. CPR of SFC_min is caled CPR_ek
- CPR available range shrinks for real engine

EXAMPLE OF ENGINE OPTIMIZATION RESULTS



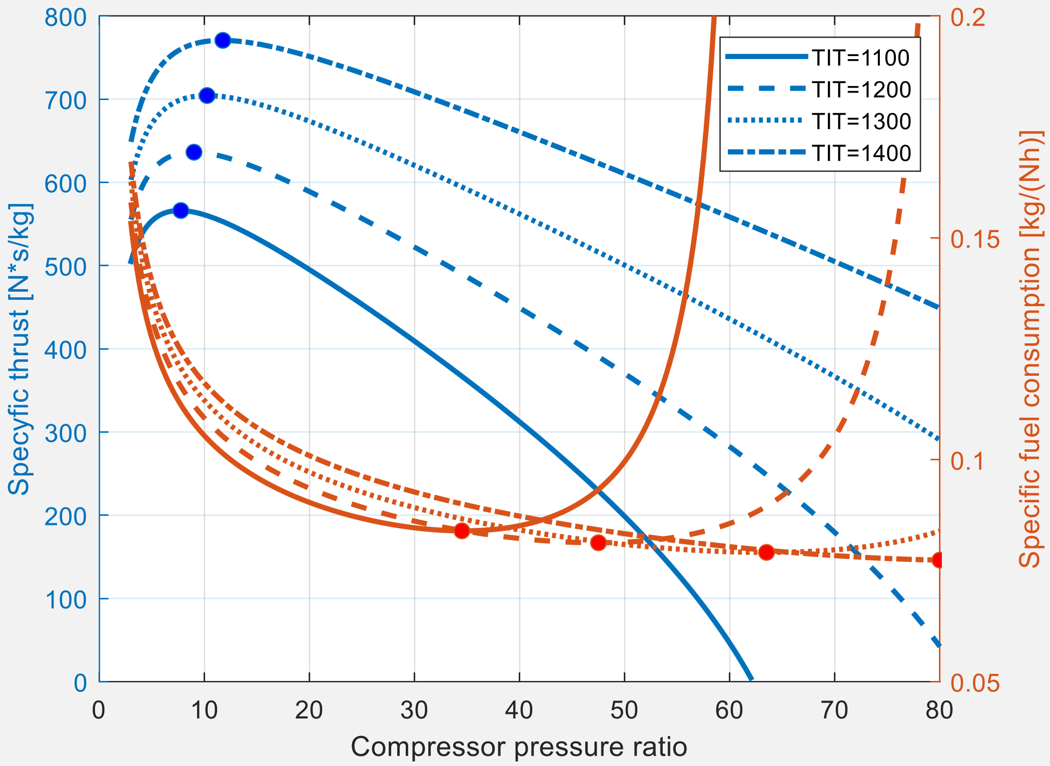


Calculation of the real and the ideal engine was prowided for the same TIT (T_{t4}) and for the same flight codition (H, M_0)

	Parameter	Value	Parameter	Value
1	'CPR(ST_max)'	9	'CPR(eta_p_min)'	9.2500
2	'CPR(SFC_min)'	47.5000	'CPR(eta_o_max)'	47.5000
3	''	NaN	'CPR(eta_th_max)'	28.7500

- Propulsive efficiency as a function of CPR represents opposite relation to ST, it is minimal for optimal CPR
- Overall efficiency represents opposite relation to SFC and it achieves maximum for minimum SFC
- For flight speed 0 thermal efficency represent opposite trend fo SFC and it achieves maximum for SFC minimum

TIT (T_4) INFLUENCES ON OPTIMAL PATAMETERS

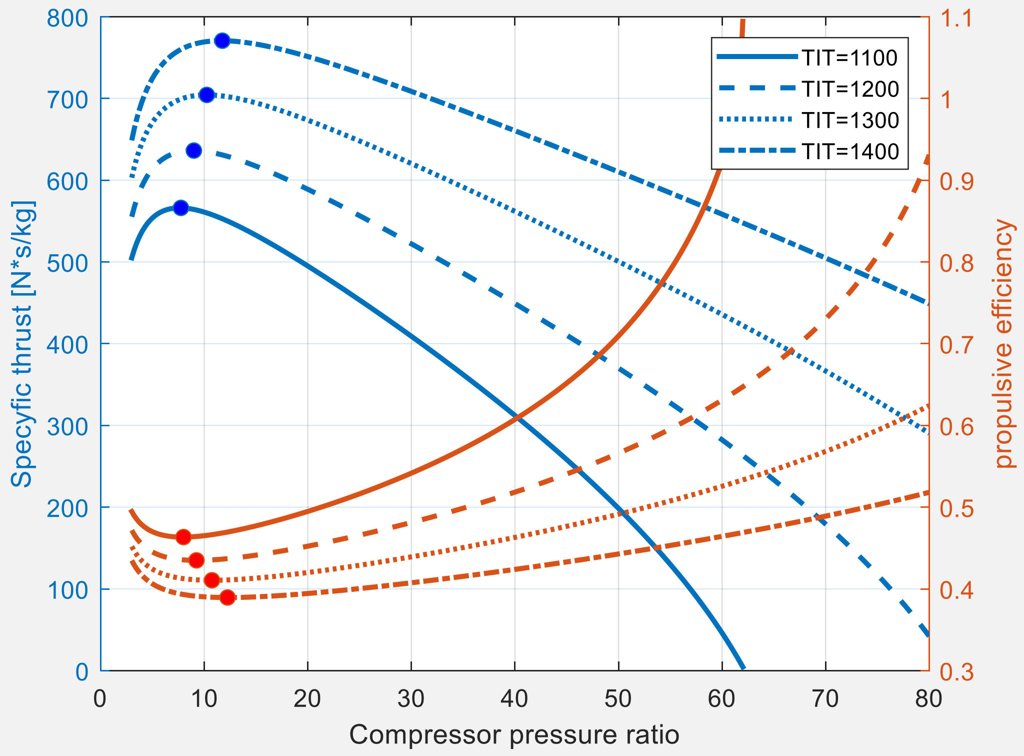


SUMMARY:

- Specific thrust (ST) is higher for higher TIT
- Maximim ST is higher for higher TIT and is achieved for slightly higher CPR
- SFC achieves minimum value on lower level for higher TIT and for higher CPR

	TIT [K]	CPR(ST_max)	ST_max [Ns/kg]	CPR(SFC_min)	SFC_min [kg/(Nh)]
1	1100	7.7500	566.0651	34.5000	0.0840
2	1200	9	636.1510	47.5000	0.0813
3	1300	10.2500	704.2687	63.5000	0.0791
4	1400	11.7500	770.5643	80	0.0774

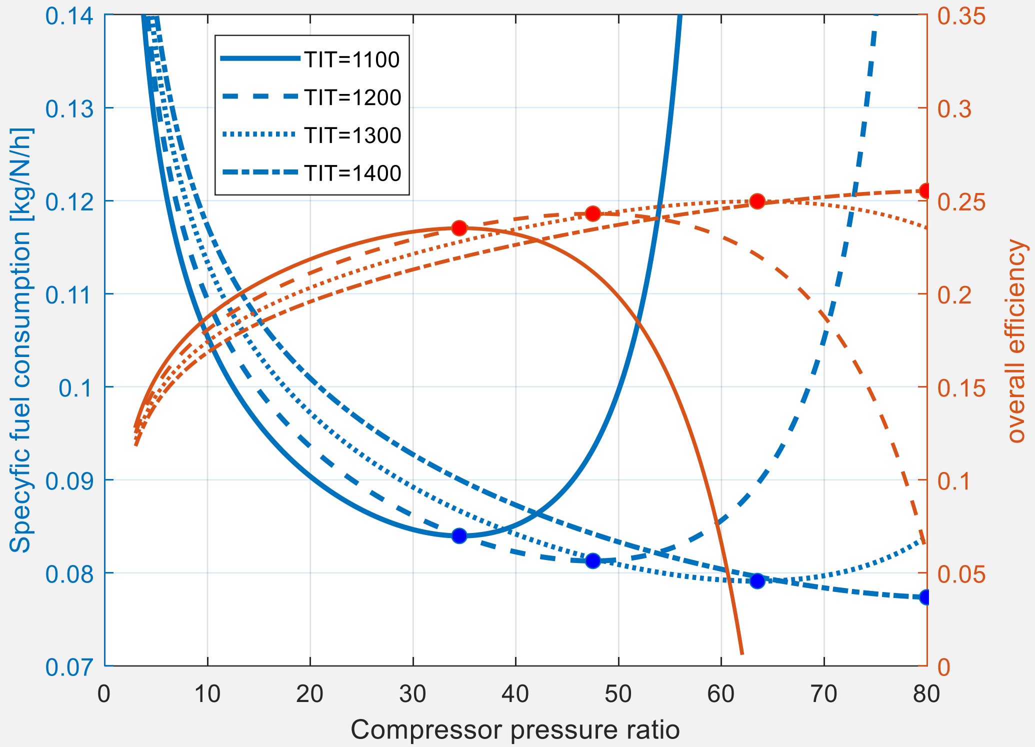
SPECIFIC THRUST VS PROPULSIVE EFFICIENCY



- Presented results confirm that ST is an opposite relation to propulsive efficiency.
- ST maximum for various TIT is consistent with minimum of propulsive efficiency for the same TIT

	TIT [K]	CPR(ST_max)	ST_max [Ns/kg]	CPR(etha_p_min)	etha_p_min
1	1100	7.7500	566.0651	8	0.4634
2	1200	9	636.1510	9.2500	0.4349
3	1300	10.2500	704.2687	10.7500	0.4106
4	1400	11.7500	770.5643	12.2500	0.3894

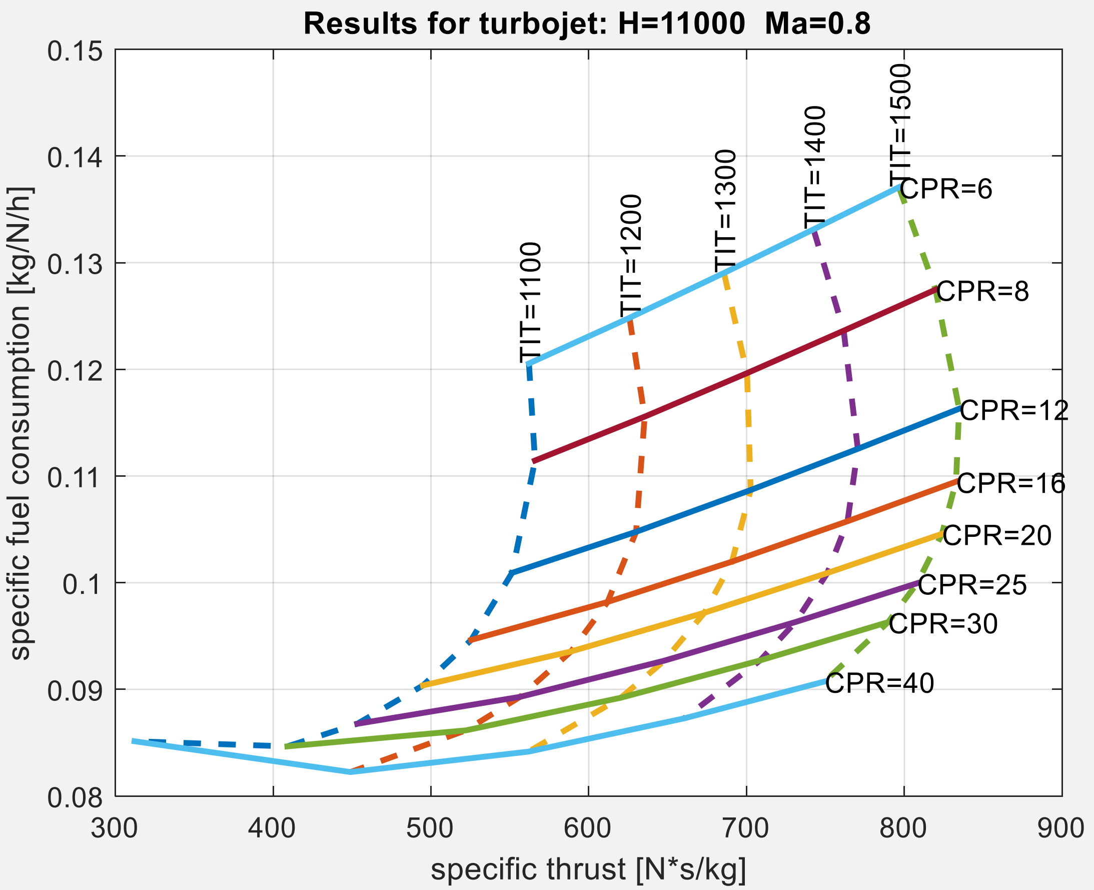
SPECIFIC FUEL CONSUMPTION VS OVERALL EFFICIENCY



- Presented results confirm that SFC is an opposite relation to overall efficiency.
- SFC minimum for various TIT is consistent with maximum of overall efficiency for the same TIT

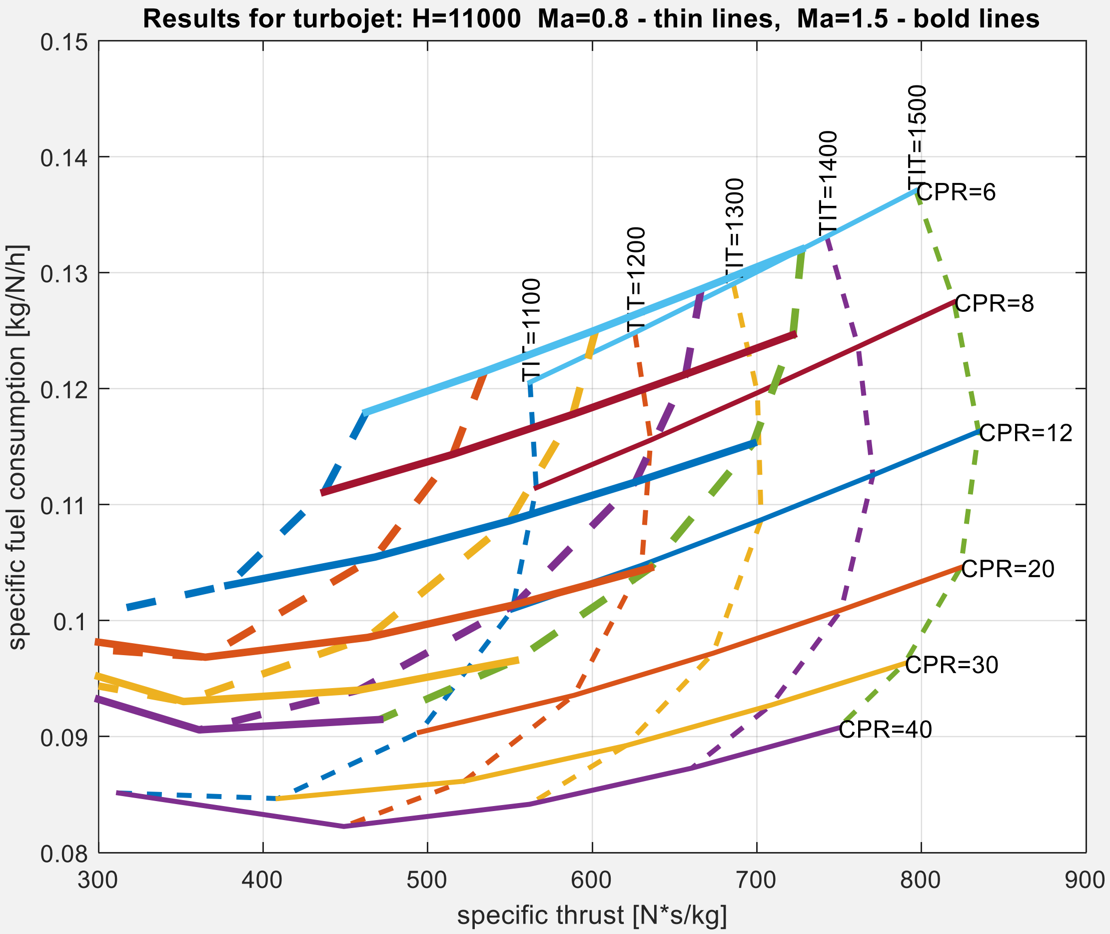
	TIT [K]	CPR(SFC_min)	SFC_min [kg/N/h]	CPR(etha_o_max)	etha_o_max
1	1100	34.5000	2.3326e-05	34.5000	0.2352
2	1200	47.5000	2.2579e-05	47.5000	0.2430
3	1300	63.5000	2.1978e-05	63.5000	0.2496
4	1400	80	2.1494e-05	80	0.2552

SFC VS ST FOR VARIOUS CPR AND TIT



- CPR growth decreases SFC
- TIT growth increases ST
- Engine performance increasing is possible by TIT and CPR growth at the same time

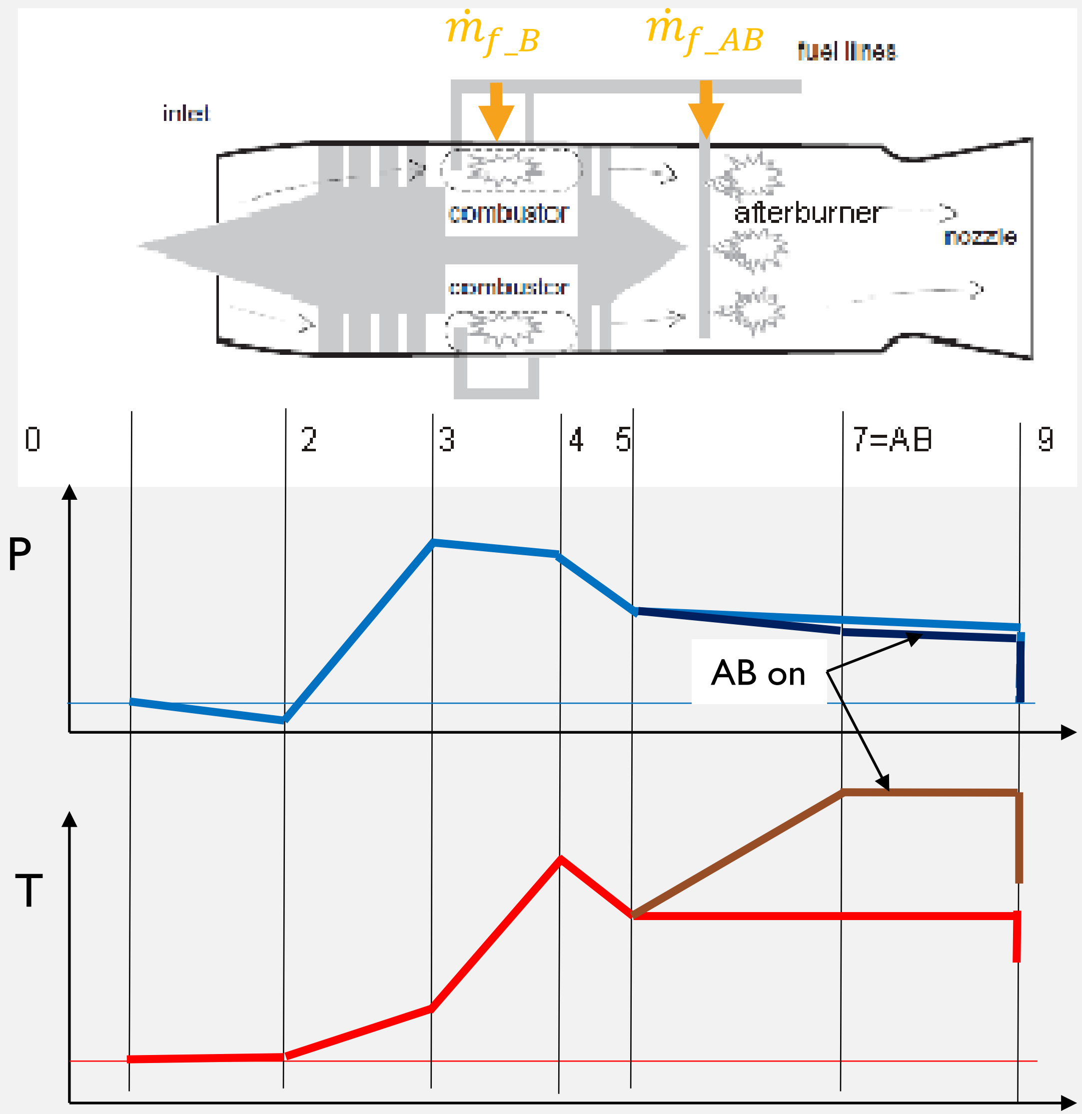
FLIGHT SPEED INFLUENCE ON SFC-ST PLOT



Higher M0 leads to:

- SFC increase
- ST decrease
- Worse conditions appears for higher CPR

TURBOJET ENGINE WITH AFTERBURNER



THTUST

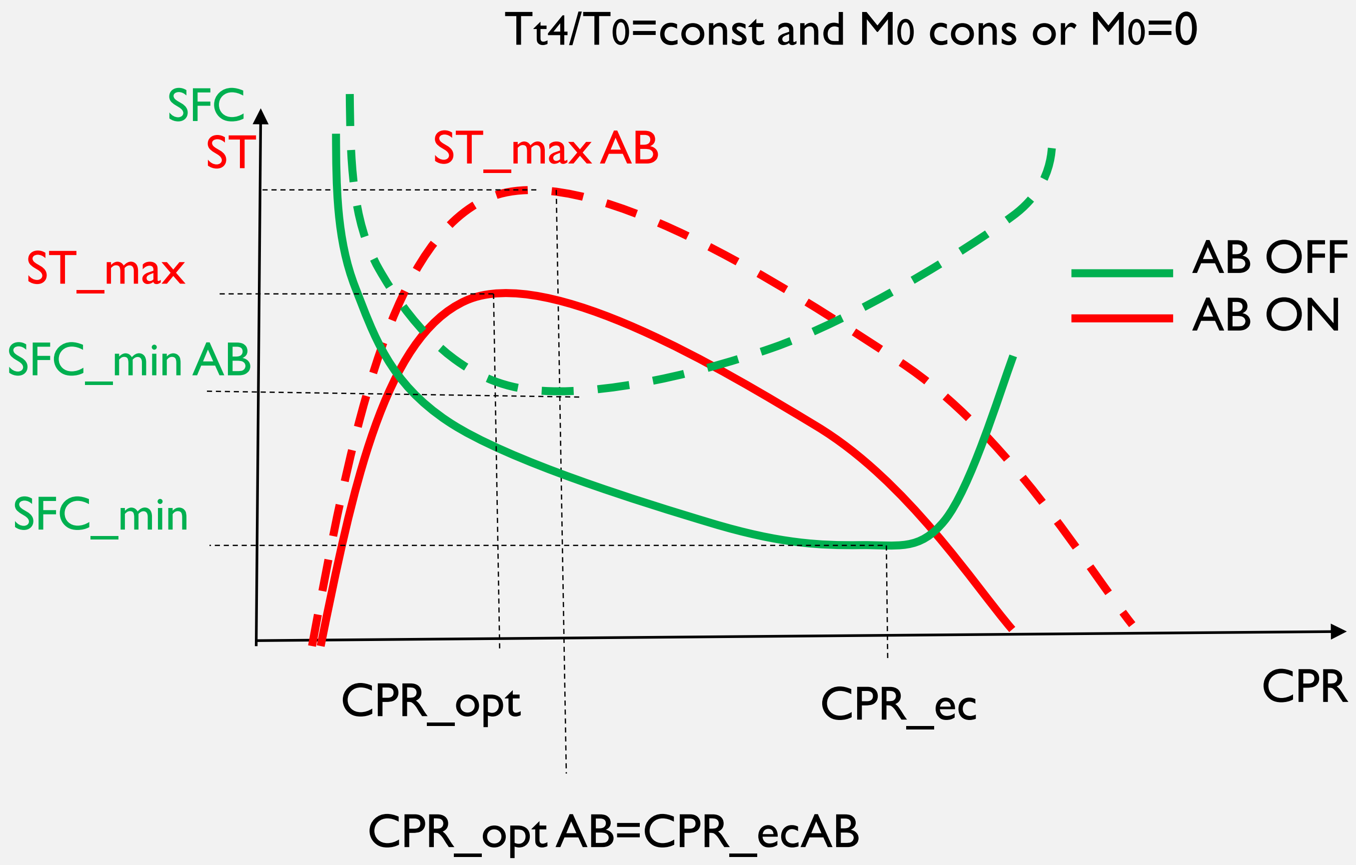
$$T_{AB} = \dot{m}_{9\_AB}V_{9\_AB} + A_{9\_AB}\left(P_{9\_AB} - P_a\right) - \dot{m}_0 V_0 = \dot{m}_{9\_AB}V_{eff\_AB} - \dot{m}_0 V_0$$

$$\dot{m}_{9\_AB} = \dot{m}_0 + \dot{m}_f \qquad \dot{m}_f = \dot{m}_{f\_B} + \dot{m}_{f\_AB}$$

SPECIFIC FUEL CONSUMPTION

$$SCF_{AB} = \dot{m}_f / T_{AB}$$

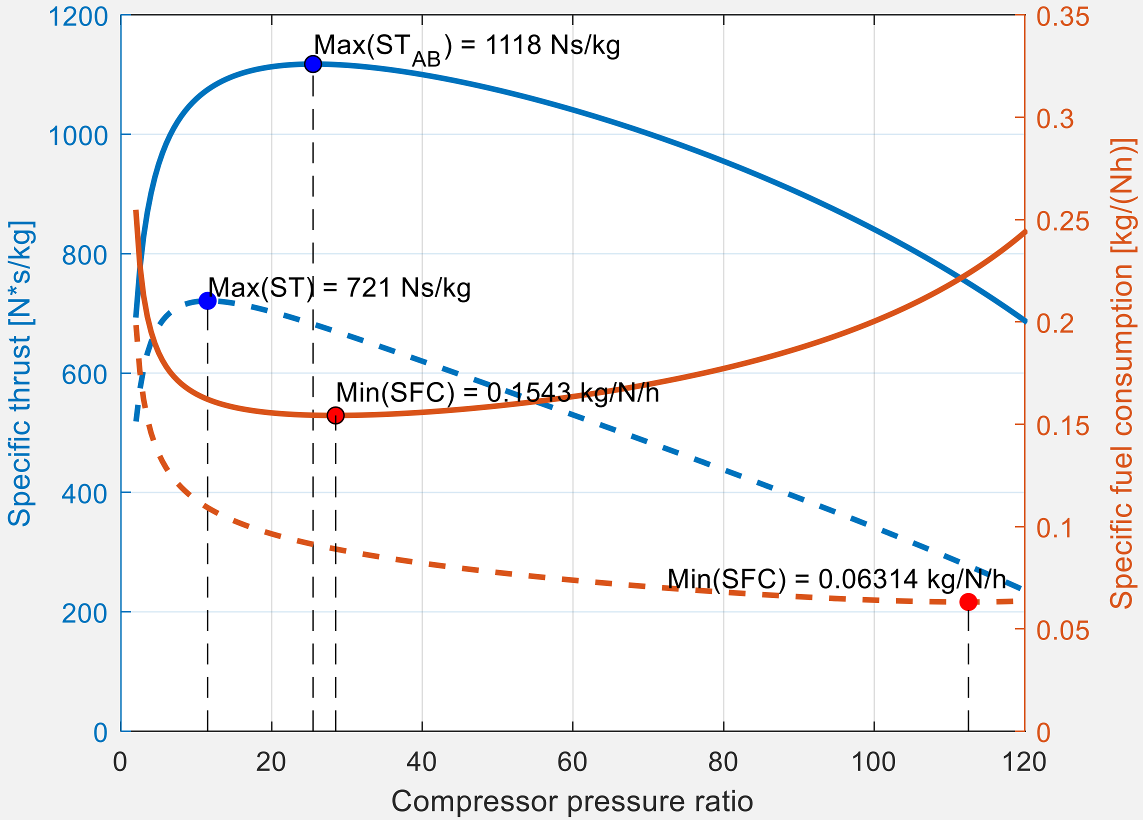
TURBOJET CYCLE OPTIMISATION REAL VS IDEAL



SUMMARY:

- Specific thrust (ST) for AB ON engine mode is higher and achieves maximum for higher CPR than for AB OFF engine
- Specific fuel consumption (SFC) for AB ON engine mode is higher and achieves minimum for lower CPR than for for AB OFF engine
- CPR_op and CPR_ec for AB ON engine are almost equal. It is posiible to find CPR for AB ON engine mode taht meets both the minimum SFC and the maximum ST criteria.

EXAMPLE OF AB_ON AB_OF ENGINE OPTIMIZATION RESULTS

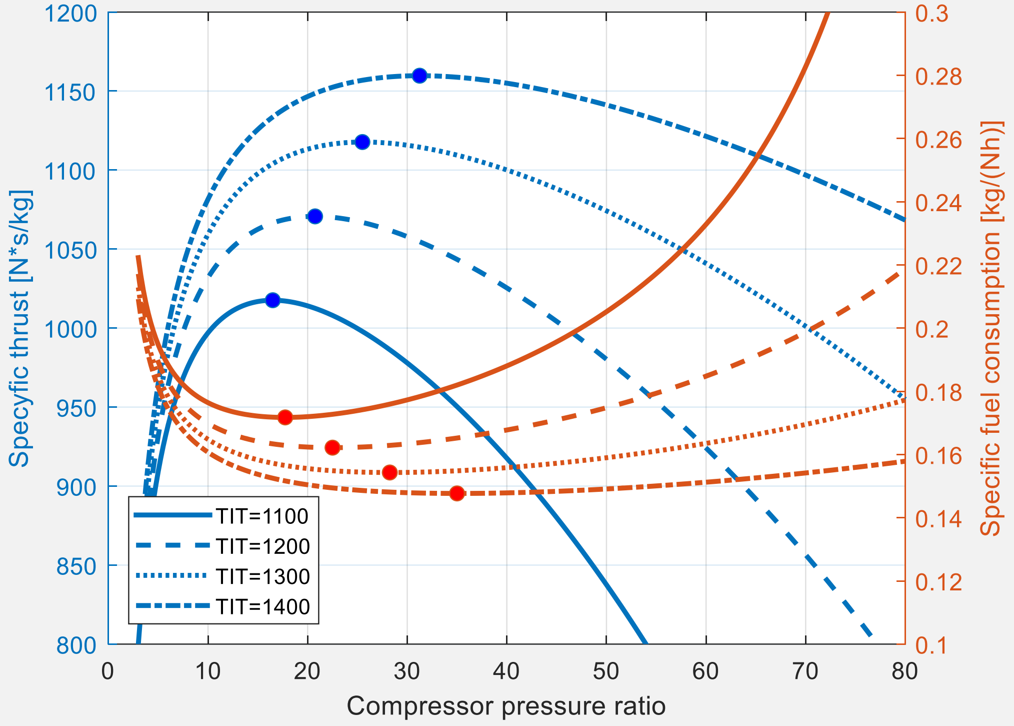


Calculation of the both engines engine was prowided for the same TIT (T_{t4}) and for the same flight codition (H, M_0). For AB ON mode aditionaly TAB was specified

	Parameter	Value
1	'CPR(ST_max)'	11.5000
2	'CPR(SFC_min)'	112.5000
3	'CPR(ST_AB_max)'	25.5000
4	'CPR(SFC_AB_min)'	28.5000

In detailed analysis CPRs of maximum ST and minimum SFC for AB ON mode are slightly different, CPR of min SFC is a little bit higher than CPR of max ST

SFC AND ST VS CPR FOR VARIOUS TET



SFC is lower for higher TIT (it is slightly different than for turbojet without AB)
The difference between CPRs for max ST and min SFC grows for higher TIT

	TIT [K]	CPR(ST_max)	ST_max [kNs/kg]	CPR(SFC_min)	SFC_min [kg/(Nh)]
1	1100	16.5000	1.0176	17.7500	0.1717
2	1200	20.7500	1.0707	22.5000	0.1622
3	1300	25.5000	1.1177	28.2500	0.1543
4	1400	31.2500	1.1597	35	0.1477

THANKS FOR YOUR ATENTION

Questions and Comments ?

1. …….
2. …….
3. …….