MECA2550 Aircraft propulsion systems

HW2 : Turbojet cycle analysis

Hand-out : Nov 22, 2016
Hand-in : Dec 5, 2016

Guidelines

Submission : Submit a written or typed report with your answers and graphics.

Code submission : Submit your code on the moodle website.

1 Turbojet optimum compressor ratio

Derive the expressions of the optimum pressure and temperature ratios $\pi_{c,\max F/\dot{m}}$ and $\tau_{c,\max F/\dot{m}}$ across the compressor of an ideal turbojet. These ratios are defined as those maximizing the engine (specific) thrust.

Compare them to the expression of the optimum compression ratio for the standard Brayton cycle, what do you notice ?

2 Hybrid cycle after-burning turbojet

We study the behavior of the J-58 engine, (used in the SR-71 Blackbird). This is an afterburning turbojet which achieves a Combined Cycle conversion. At high Mach numbers, the engine can be converted into a ramjet : the compressor, burner and turbine are bypassed. The air flow goes directly to the afterburner.

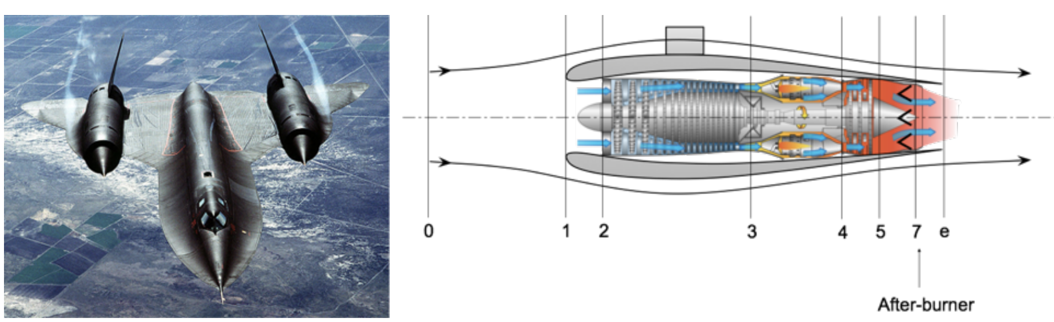

Figure 1 – Lockheed-Martin SR-71 *Blackbird*

1. Carry out the ideal cycle analysis for the after-burning turbojet to find its specific thrust. Note that, compared to the turbojet, you will now have to add the parameter $\tau_{\lambda,AB}$ to enforce the maximum stagnation temperature in the after-burner.
2. Use your analysis from 1.1) to obtain the specific thrust when the engine works as a ramjet. (Hint : what is happening to τ_c, τ_t, τ_b, π_c, π_t, π_b)
3. Use these two expressions to deduce the condition on the Mach number at which one should transition from the after-burning turbojet to the ramjet mode. It is a somewhat simple function $M_{\text{ABTJ To Ram}}(\tau_c, \tau_t \ldots)$. Apply it to the flight conditions and engine parameters given below.
4. Verify your formula : apply your answers to questions 1 and 2 to Mach numbers M=[2..., $M_{\text{ABTJ To Ram}}$(your numerical answer to 1.3), ... 3.5]. Comment your answer !
5. Can you give an interpretation of what happens to the cycle ? Use the (T-s) diagrams.
6. What happens to the thrust specific fuel consumption ?

TABLE 1 – Data : SR 71 flight conditions and engine parameters

Variable		Value	Units
Altitude	z	20000	m
Pressure	p_0	5475	Pa
Temperature	T_0	216	K
Density	ρ_0	0.088	kg m-3
Specific heat ratio	γ	1.4	
Mach	M_0	...	

Variable		Value	Units
Compression ratio	π_c	20	
Turbine inlet Temperature	T_{t4}	1400	K
Afterburner Temperature	T_{t7}	2300	K
Fuel lower heating value	LHV	$43.19\ 10^6$	J kg^{-1}

3 Losses

We introduce losses in the parametric study of the after-burning turbojet, in the form of polytropic efficiencies $e_c = e_t = 0.9$. Perform the cycle analysis and plot the new behaviors of the specific thrust and fuel consumption.