Ranges for F100-PW-220 Engine Model

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October 21, 2015

1 Purpose

This document summarizes the common input design variables for the F100-PW-220 engine model (`turbofanF100.m`), and the associated nozzle model (`nozzleNonIdeal.m`). It provides design variable ranges, as well as the reasons for the chosen ranges.

2 Design Variable Ranges

Design variable ranges are discussed separately for both variables used in the engine model, and for variables used in the nozzle model.

2.1 Common Engine Model Variables

In addition to the common engine model variables, the engine and nozzle models can be run at a variety of altitudes and Mach numbers. However, certain combinations of altitude and Mach number lead to off-design conditions, which are not take into consideration with the model. To ensure that calculations are performed within a feasible design space with the range of variables given in Table 2, ensure that for a given altitude, the chosen Mach number is above the minimum Mach number in Table 1.

Bypass ratio Nominal value is well agreed upon in literature (Camm, Jane's, Allstar). Nominal value is taken to be rounded average of 2 values found. Range spans a little less than 10% of nominal value.

Fan stag. pressure ratio Nominal value is cited by trustworthy source (Jane's Aero Engines). Stated range spans 5% of nominal value.

Fan polytropic efficiency Typical range for this efficiency based on Lee's paper.

Table 1: Minimum Mach number for a given altitude

Altitude (thousands of ft)	Minimum Mach
0	0
10	0
15	0.25
20	0.42
25	0.54
30	0.63
35	0.7
40	0.72

Table 2: Ranges for engine design variables

Parameter	Variable (`control.xxx`)	Minimum	Nominal	Maximum
Bypass ratio	`bypassRatio`	0.59	0.62	0.64
Fan stag. pressure ratio	`fan.PstagRatio`	2.99	3.06	3.14
Fan polytropic efficiency	`fan.efficiency.polytropic`	0.82	0.84	0.86
Compressor overall pressure ratio	`compressor.overallPressureRatio`	24	24.5	25
Compressor polytropic efficiency	`compressor.efficiency.polytropic`	0.84	0.87	0.9
Burner stag. pressure ratio	`burner.PstagRatio`	0.92	0.95	0.98
Burner efficiency	`burner.efficiency`	0.94	0.95	0.99
Turbine polytropic efficiency	`turbine.efficiency.polytropic`	0.83	0.85	0.89
Turbine shaft efficiency	`turbine.efficiency.shaft`	0.95	0.97	0.99
Bypass area to core area ratio	`nozzle.inlet.Abypass2Acore`	0.38	0.4	0.42
Nozzle inlet diameter	`nozzle.inlet.D`		0.651	
Nozzle inlet to throat area ratio	`geometry.Ainlet2Athroat`		1.368	
Nozzle exit to throat area ratio	`geometry.Aexit2Athroat`		1.4	

Compressor overall pressure ratio Nominal value taken from Jane's. All values quoted in literature span the given range.

Compressor polytropic efficiency Typical range for this efficiency based on Lee's paper.

Burner stag. pressure ratio Typical range for this efficiency based on Lee's paper.

Burner efficiency Typical range for this efficiency based on Lee's paper. Nominal value chosen so deterministic static sea level thrust better matches experimental data in literature.

Turbine polytropic efficiency Typical range for this efficiency based on Lee's paper. Nominal value chosen so deterministic static sea level thrust better matches experimental data in literature.

Turbine shaft efficiency Typical range for this efficiency based on Lee's paper.

Bypass area to core area ratio Minimum value set so that supersonic flow does not occur in the bypass duct anywhere in the X-47B's estimated operating envelope. Max value chosen to give a 10% range (rounded up). This variable is only used when the fan bypass and turbine core air flows are area-averaged, which is a design choice leading to greater model form uncertainty. Thus, there is a certain nebulousness to this variable, firstly, because it represents a ratio that is not known (and can only be estimated from non-technical drawings) and secondly, because it is used as an input only for a very simple modeling approximation. Note that, were this engine being designed in house, its value would be pinpointed with much greater accuracy. As such, the lowest reasonable range which will not cause supersonic flow in the bypass duct has been assumed.

Nozzle inlet diameter Assumed to be deterministic. Nominal value measured from a Pratt & Whitney non-technical drawing and adjusted for decent matching with static sea level thrust experimental data.

Nozzle inlet to throat area ratio Assumed to be deterministic. Nominal value estimated from a Pratt & Whitney non-technical drawing and adjusted for decent matching with static sea level thrust experimental data.

Nozzle exit to throat area ratio Assumed to be deterministic. Nominal value estimated from a Pratt & Whitney non-technical drawing and adjusted for decent matching with static sea level thrust experimental data.

2.1.1 Notes

Supersonic flow in bypass duct Concerning supersonic flow in the fan bypass duct, the most critical combination of variables has been found to be an engine model with maximum bypass ratio, maximum fan, compressor, and turbine polytropic efficiencies, maximum turbine shaft efficiency, minimum fan stagnation pressure ratio, maximum burner stagnation pressure ratio, and of course, minimum bypass to core area ratio. At these conditions, with the ranges given above, very high subsonic flow is present in the fan bypass duct. (10/21/15)

2.2 Common Nozzle Model Variables

To be updated soon.

References