Gas Turbine Performance Analysis Using GasTurb 14

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This report documents three stages of a gas–turbine performance study using GasTurb 14. HW1 verifies a GasTurb design–point model against the existing HW9 hand analysis of a high–bypass, two–spool turbofan. HW2 uses the verified model to perform a two–parameter design–space study of high–pressure compressor pressure ratio and turbine inlet temperature at cruise, identifying a broad valley of low thrust specific fuel consumption (TSFC) with a minimum of about $21\ \mathbf{g/(kN\,s)}$ **near** $\pi_c \approx 20$ **and** $T_4 = 1650$ **K. HW3 then evaluates off–design operability using compressor maps, computing operating lines at several altitudes and examining surge margin as a function of corrected HP spool speed. At the nominal cruise condition the high–pressure compressor surge margin remains above roughly** 30% **over the normal operating range of corrected spool speeds. Together, these steps show how a simple analytical Brayton–cycle model [1, 2] can be extended into a more realistic engine–modeling workflow using GasTurb [3].**

Nomenclature

M_∞	Freestream Mach number
$T_a,\ p_a$	Ambient static temperature and pressure
$T_1,\ P_1$	Inlet total temperature and pressure
T_4	Turbine inlet (burner exit) total temperature
$T_7,\ p_7$	Core nozzle exit static temperature and pressure
$T_9,\ p_9$	Bypass nozzle exit static temperature and pressure
$T_{t5},\ p_{t5}$	Turbine exit total temperature and pressure
P_3/P_2	Overall compressor total–pressure ratio (engine inlet to HPC exit)
P_{25}	Total pressure at HPC inlet (station 25)
$P_{t3}/P_{t\infty}$	Overall total–pressure ratio (freestream to HPC exit)
π_d	Diffuser (intake) total–pressure ratio
π_f	Fan total–pressure ratio
π_c	High–pressure compressor total–pressure ratio
$\pi_{c,\text{surge}}$	Compressor pressure ratio at surge line (at given corrected flow)
$\pi_{c,\text{op}}$	Compressor pressure ratio on operating line (at given corrected flow)
β	Bypass ratio (bypass/core mass–flow ratio)
BPR	Bypass ratio (alternate notation)
TSFC	Thrust specific fuel consumption
F_N	Net thrust
$\dot{m}$	Engine mass flow rate
N	High–pressure spool speed
N_{corr}	Corrected high–pressure spool speed
$T_{t,\text{in}}$	Compressor inlet total temperature
T_{ref}	Reference total temperature for corrected speed
SM	Compressor surge margin
η_p	Polytropic efficiency

1. Introduction

Modern gas turbine engines are designed and analyzed using cycle models that combine component performance, thermodynamic properties, and operating constraints [1, 2]. In AE 433, Homework 9 developed an analytical design–point model of a high–bypass–ratio, two–spool turbofan using ideal–gas relations with constant specific heats and prescribed component efficiencies. That model is useful for hand calculations and basic sensitivity studies, but it neglects several effects that are important for real engines, such as temperature–dependent gas properties, detailed compressor and turbine maps, secondary air systems, and realistic nozzle expansion.

GasTurb 14 is a gas turbine performance code that includes these additional effects while remaining relatively easy to set up and run [3]. The goal of this project is to learn how to use GasTurb to build, check, and explore gas turbine cycle models in a way that is consistent with the

HW9 analytical framework and AE 433 course notes [4]. The project consists of three stages. HW1 focuses on design–point verification by reproducing the HW9 turbofan in GasTurb and quantifying the differences between the hand analysis and the software model. HW2 uses the verified model to perform parametric sweeps of key design variables such as overall compressor pressure ratio and turbine inlet temperature. HW3 then extends the analysis to off–design operating conditions, using compressor maps to assess operability and surge margin. This report presents the methods and results for all three stages, following the AE 433 GasTurb project guidelines [5].

2. Methodology and Verification (HW1)

2.1. HW9 Baseline Turbofan

The baseline cycle is the two–spool unmixed–flow turbofan analyzed in HW9. The design–point flight condition and cycle parameters are

- Flight Mach number: $M_\infty = 0.88$.
- Ambient temperature and pressure: $T_a = 269$ K, $p_a = 15$ kPa.
- Diffuser total–pressure ratio: $\pi_d = 0.995$.
- Fan pressure ratio: $\pi_f = 1.6$.
- High–pressure compressor pressure ratio: $\pi_c = 40$.
- Bypass ratio: $\beta = 8$.
- Turbine inlet (burner exit) temperature: $T_4 = 1625$ K.

In HW9 these parameters were combined with assumed component efficiencies, constant specific heats, and idealized nozzle expansion to compute station temperatures and pressures, fuel–air ratio, thrust specific fuel consumption (TSFC), and other performance metrics.

2.2. GasTurb Model Setup

For HW1, the GasTurb demo file `Demo_tf.CYF` for a two–spool unmixed–flow turbofan was used as a starting point. The engine type was kept unchanged, and the design–point calculation was performed using the *Design Point* module in GasTurb 14. The ambient condition input mode was switched to the *T1, P1, Pamb* option, where total temperature, total pressure, ambient pressure, and Mach number are specified directly. Table 1 summarizes the inputs that were changed relative to the demo file in order to match the HW9 design point.

Table 1. Key GasTurb design–point inputs changed from the `Demo_tf.CYF` default to reproduce the HW9 turbofan.

Category	Input parameter	Value	Rationale
Ambient	M_∞	0.88	Match HW9 flight Mach number.
	T_1	269 K	Match HW9 ambient temperature.
	P_1, P_{amb}	15 kPa	Match HW9 ambient pressure.
Inlet	Intake total–pressure ratio π_d	0.995	Use HW9 diffuser loss.
Fan / LPC	Inner fan pressure ratio	1.0	No additional core compression in inner fan.
	Outer fan pressure ratio π_f	1.6	Match HW9 fan pressure ratio.
HPC	HP compressor pressure ratio π_c	40	Match HW9 core compressor pressure ratio.
Bypass	Design bypass ratio β	8	Match HW9 bypass ratio.
Combustor	Burner exit temperature T_4	1625 K	Match HW9 turbine inlet temperature.
	Power offtake	0 kW	No shaft power extraction at design point.
Turbines	HP turbine stages	1	Simplify to single–stage HP turbine.
	LP turbine stages	1	Simplify to single–stage LP turbine.

All other inputs (polytropic efficiencies, mechanical efficiencies, bleed and cooling fractions, and default nozzle thrust coefficients) were left at their demo values. After these changes, the GasTurb design point converged without warnings. The resulting summary shows an overall compressor pressure ratio $P_3/P_2 \approx 39.6$, fan pressure ratio $P_{25}/P_{21} = 1.6$, bypass ratio $\beta = 8.0$, and turbine inlet temperature $T_4 \approx 1625$ K, confirming that the software model reproduces the HW9 design–point specification.

2.3. Comparison with Analytical HW9 Results

Key design–point outputs from GasTurb were extracted from the *Summary* and *Station Data* windows and compared to the HW9 analytical results. The quantities of interest are:

- Overall thrust specific fuel consumption (TSFC).
- Core nozzle exit static temperature and pressure (T_7, p_7).
- Bypass nozzle exit static temperature and pressure (T_9, p_9).
- Turbine exit total (stagnation) temperature and pressure (T_{t5}, p_{t5}).
- Velocity ratio between the bypass and core streams, $u_{\text{bypass}}/u_{\text{core}}$.

Table 2 summarizes the comparison between the HW9 hand–calculated values and the GasTurb predictions.

Table 2. Comparison of HW9 analytical results and GasTurb 14 design–point predictions for the HW9 turbofan.

Quantity	HW9 value	GasTurb value	Percent difference
TSFC [g/(kN·s)]	19.4	8.546	−55.9%
Core nozzle static T_7 [K]	770	792.91	+3.0%
Core nozzle static p_7 [kPa]	45.4	19.237	−57.6%
Bypass nozzle static T_9 [K]	257	311.96	+21.4%
Bypass nozzle static p_9 [kPa]	19.8	23.402	+18.2%
Turbine exit T_{t5} [K]	897	1099.24	+22.5%
Turbine exit p_{t5} [kPa]	85.7	89.187	+4.1%
Velocity ratio $u_{\text{bypass}}/u_{\text{core}}$	0.46	0.82564	+79.5%

Row–by–row explanations. For TSFC, GasTurb predicts a much lower value, meaning better fuel efficiency. This indicates that the simplified HW9 model substantially overpredicts TSFC for this notional engine, likely because of its use of constant properties, idealized nozzle sizing, and approximate mass–flow assumptions. Since no experimental engine data are available, the absolute value of TSFC cannot be validated, but the comparison still highlights how sensitive TSFC is to modeling details.

For the core nozzle exit (T_7, p_7), the GasTurb temperature is only slightly higher but the pressure is much lower. This suggests that turbine and duct losses are larger and that the core nozzle expansion is less ideal than the perfectly expanded, lossless nozzle assumed in HW9.

For the bypass nozzle exit (T_9, p_9), GasTurb gives a hotter and higher–pressure bypass jet. The fan flow in GasTurb experiences polytropic compression and duct losses, while the HW9 bypass stream is treated as nearly ideal, so the bypass jet in the software model carries more enthalpy and momentum.

At the turbine exit (T_{t5}, p_{t5}), GasTurb predicts a higher stagnation temperature and a slightly higher pressure. With variable c_p and γ and polytropic efficiencies, the turbine needs a different enthalpy drop to supply the required shaft work, which shifts the exit state compared to the HW9 assumptions.

Finally, the bypass–to–core velocity ratio $u_{\text{bypass}}/u_{\text{core}}$ is much larger in GasTurb. In the software, the jet velocities result from area sizing and thrust coefficients that satisfy momentum balance, while HW9 uses a more idealized, "optimum" type assumption. As a result, the bypass stream is modeled as significantly faster in GasTurb than in the HW9 hand calculation.

The overall trends in Table 2 can therefore be understood in terms of modeling assumptions. GasTurb uses temperature–dependent specific heats and ratio of specific heats for both air and combustion products, whereas the HW9 analysis assumes constant c_p and γ for each medium. This changes the relationship between temperature, enthalpy, and work throughout the cycle, which in turn affects the required fuel–air ratio and the nozzle exit velocities. GasTurb also models compressors and turbines using polytropic efficiencies and includes mechanical efficiency losses on each spool, while the HW9 model prescribes overall adiabatic efficiencies. In addition, the

GasTurb demo engine includes small but nonzero bleed and cooling flows in the secondary air system, which are not explicitly modeled in HW9. Finally, the nozzle expansion in GasTurb uses thrust coefficients and area sizing to satisfy momentum balance, rather than the idealized perfectly expanded, choked–nozzle assumption used in the hand calculation. Together, these differences lead to a lower TSFC and somewhat different station states in the GasTurb model. Figure 1 shows the same design–point cycle plotted on a temperature–entropy diagram generated by GasTurb.

2.4. Verification Versus Validation

This homework is a *verification* exercise rather than a full validation. Verification asks whether a numerical model correctly implements the governing equations and assumptions of a given conceptual model, whereas validation compares model predictions directly to experimental data [4]. In HW1, the GasTurb model was verified against the existing HW9 analytical cycle by matching the primary design–point inputs and checking that the resulting station states and TSFC are reasonable and consistent in trend. No experimental engine data were used, so the model has not been validated. Even so, the exercise builds confidence that GasTurb is configured correctly and that the software can be used as a reliable tool in the later parametric and off–design analyses.

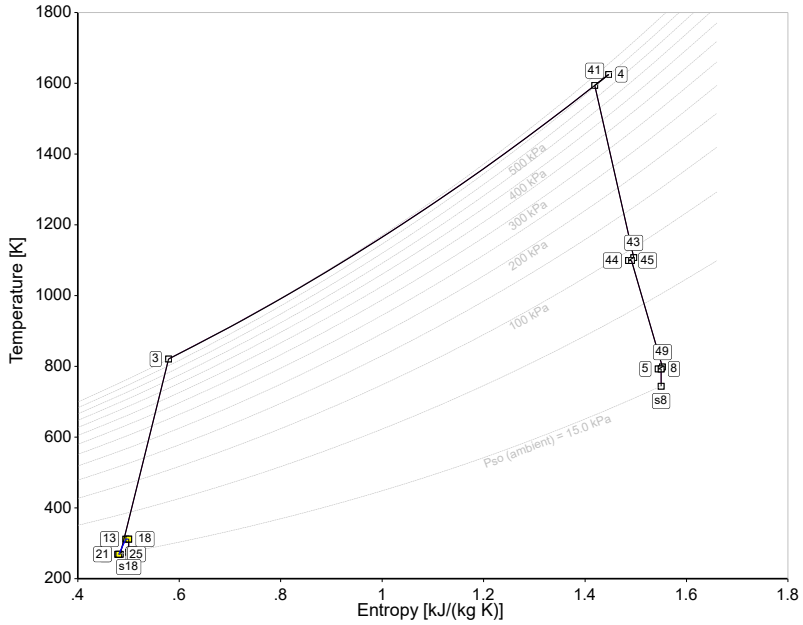


Fig. 1. Temperature–entropy diagram for the HW9 turbofan design–point cycle generated using GasTurb 14. Points are labeled using the GasTurb station numbering for the fan, compressor, combustor, turbines, and nozzles.

For reference, the HW9 hand analysis predicts a design–point TSFC of about 19 $\mathrm{g}/(\mathrm{kN}\cdot\mathrm{s})$, whereas GasTurb gives TSFC = 8.55 $\mathrm{g}/(\mathrm{kN}\cdot\mathrm{s})$ for the same nominal cycle. The factor–of–two difference underscores how strongly TSFC depends on modeling assumptions. For this project, agreement in the *trends* of station properties and performance metrics is taken as the main verification

criterion, rather than exact numerical agreement.

3. Parametric Study of Compressor Ratio and Turbine Inlet Temperature (HW2)

Homework 2 uses GasTurb to explore how thrust specific fuel consumption (TSFC) changes with overall compressor ratio and turbine inlet temperature for a modern, high–bypass turbofan. The engine model is based on a CFM56–type two–spool, unmixed–flow turbofan suitable for a single–aisle transport aircraft [2].

3.1. Engine Setup for HW2

The HW2 engine uses the same general layout as HW1 (two spools, separate core and bypass nozzles), but with parameters more representative of a CFM56–class turbofan:

- Flight condition: altitude 11,000 m, $M_\infty = 0.80$, ISA atmosphere.
- Bypass ratio: $BPR \approx 5.5$.
- HP compressor pressure ratio: baseline value $\pi_c = 20$.
- Burner exit (turbine inlet) temperature: baseline $T_4 = 1650$ K.
- Intake, burner and turbine duct pressure ratios and component polytropic efficiencies were kept at the GasTurb demo values.
- Secondary air system, bleed and cooling flows were also kept at their default settings.

Table 3 summarizes the key design–point parameters for the HW2 engine and indicates whether they are prescribed or taken from GasTurb defaults.

Table 3. Key design–point parameters for the HW2 CFM56–type engine.

Category	Quantity	Value	Source / Rationale
Flight	Altitude	11,000 m	Representative cruise for single–aisle transport.
	M_∞	0.80	Typical long–range cruise Mach number [2].
Cycle	Bypass ratio BPR	≈ 5.5	CFM56–class high–bypass turbofan [2].
	HP compressor ratio π_c	20	Target overall pressure ratio $P_{t3}/P_{t\infty} \approx 30$.
	Turbine inlet temperature T_4	1650 K	Representative modern TET at cruise [2].
Components	Polytropic efficiencies	Demo values	Use GasTurb defaults for a modern engine [3].
	Duct pressure ratios	Demo values	Use GasTurb defaults for inlets/ducts.
Secondary	Bleed / cooling flows	Demo values	Maintain consistency with demo engine.

1. Design–Point Iteration Target

A GasTurb *Design Point* calculation, using the *Design Point* → *Iterations* tool, was then used to choose a baseline cruise design. The target was an overall total pressure ratio from freestream to HP compressor exit of about $P_{t3}/P_{t\infty} \approx 30$ and a TSFC near 21 g/(kN s), consistent with published values for efficient single–aisle engines [2]. The iteration varied T_4 and π_c and converged to $\pi_c = 20$ and $T_4 = 1650$ K, for which GasTurb predicts a net thrust of about $F_N = 4.06$ kN and a TSFC of

$$\text{TSFC} \approx 21.0 \text{ g/(kN s)}.$$

The corresponding total pressure ratio from the engine inlet face to the HP compressor exit is $P_3/P_2 \approx 19.8$, which aligns with the desired $P_{t3}/P_{t\infty} \approx 30$. This point is used as the baseline for the parametric study.

3.2. Two–Parameter Sweep

The GasTurb *Parametric* module was then used to vary two design parameters:

- HP compressor pressure ratio π_c from 15 to 30.
- Burner exit temperature T_4 from 1500 to 1800 K.

Both parameters were varied over eleven evenly–spaced values, giving an 11×11 grid (121 design points) in the π_c–T_4 plane. All other inputs, including bypass ratio and secondary air settings, were held fixed at their baseline values. For each point GasTurb computed a full design–point solution; TSFC and specific thrust $F_N/\dot{m}$ were extracted as the main outputs of interest. The results were plotted as a contour map of TSFC with π_c on the horizontal axis and T_4 on the vertical axis.

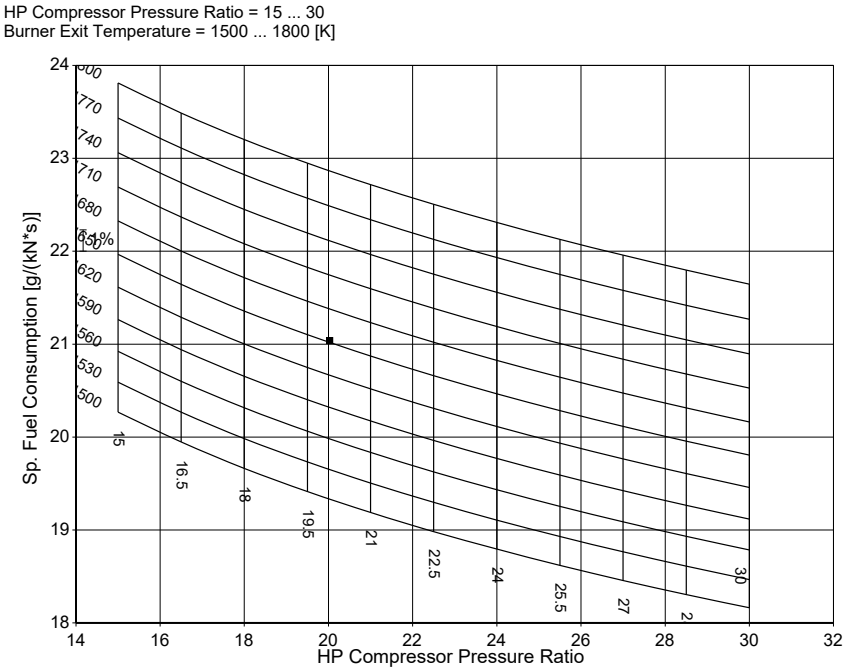


Fig. 2. Contour plot of TSFC as a function of HP compressor pressure ratio and burner exit temperature for the HW2 turbofan.

3.3. Results and Discussion

The TSFC map in Fig. 2 shows clear trends. At fixed compressor ratio, increasing T_4 generally reduces TSFC because the hotter turbine inlet temperature allows more jet power to be extracted for roughly the same mass flow. At fixed T_4, increasing π_c also tends to reduce TSFC over most of the range, since a higher compressor pressure ratio improves the thermal efficiency of the Brayton

cycle and leads to a larger exhaust velocity for a given fuel–air ratio [1]. However, the benefit of raising π_c becomes smaller at the high end of the range because the compressor work grows and the additional pressure ratio gives diminishing returns.

In addition to TSFC, the same GasTurb runs provide the specific thrust $F_N/\dot{m}$. As expected from Brayton–cycle analysis [1, 2], specific thrust increases with both π_c and T_4 because the cycle delivers a larger total temperature and pressure rise to the exhaust. Over the range considered here, specific thrust varies by roughly 10–20% across the map. The TSFC minimum does not coincide with the maximum specific thrust, which illustrates the classic design trade: higher specific thrust allows a smaller engine for a given aircraft thrust requirement, while the lowest TSFC minimizes fuel burn but can require a larger fan and core.

One representative point on the map is the baseline case $\pi_c = 20$, $T_4 = 1650$ K. At this operating condition GasTurb predicts TSFC ≈ 21.0 g/(kN s) and a total pressure ratio from the inlet to the HP compressor exit of $P_3/P_2 \approx 19.8$ (corresponding to $P_{t3}/P_{t\infty} \approx 30$). Moving toward higher π_c and higher T_4 in the contour plot reduces TSFC by a few percent, but at the cost of increased compressor and turbine temperature ratios and associated design challenges (higher blade stress, cooling requirements, and material limits). Moving toward lower π_c or lower T_4 gives a more conservative engine but with a clear penalty in TSFC.

Overall, the HW2 parametric study illustrates the familiar tradeoff for turbofan design: higher compressor pressure ratio and turbine inlet temperature improve fuel efficiency and specific thrust, but drive the engine closer to material and cooling limits [1]. The GasTurb model provides a convenient way to visualize these trends and to select design points for further off–design analysis in HW3.

To have a concrete design for the subsequent off–design analysis, a point near the TSFC minimum but with a moderate turbine inlet temperature was selected. The chosen design has an overall compressor pressure ratio of $\pi_c \approx 20$ and a burner exit temperature of $T_4 = 1650$ K, for which GasTurb predicts TSFC ≈ 21 g/(kN $\cdot$ s) at the cruise condition. This point lies on the flat bottom of the TSFC valley in Fig. 2, so small deviations in π_c or T_4 do not strongly penalize fuel consumption.

4. Off–Design Behavior and Compressor Operability (HW3)

4.1. Motivation and Key Definitions

Real engines rarely operate exactly at their design point. During climb, cruise at different altitudes, descent, and throttle transients, the compressor sees different inlet temperatures, pressures, and shaft speeds. These off–design conditions change the corrected mass flow and pressure ratio of each stage, which can move the operating point toward either the choke line (flow limit) or the surge line (stall limit). Maintaining adequate margin to surge is therefore a key operability constraint for turbofan design and control [2].

In GasTurb, off–design compressor performance is visualized using maps with families of constant corrected–speed lines. The corrected speed is a non–dimensional shaft speed,

$$N_{\mathrm{corr}} = \frac{N}{\sqrt{T_{t,\mathrm{in}}/T_{\mathrm{ref}}}}, \tag{1}$$

which removes most of the trivial dependence of shaft speed on inlet total temperature. Points that share the same corrected speed lie on the same map line even when the engine is run at different

ambient conditions.

Surge margin is a measure of the distance between the operating line and the surge line on the map. GasTurb reports it as a percentage,

$$SM = \frac{\pi_{c,\text{surge}} - \pi_{c,\text{op}}}{\pi_{c,\text{surge}}} \times 100\%, \tag{2}$$

where $\pi_{c,\text{op}}$ is the compressor pressure ratio on the operating line and $\pi_{c,\text{surge}}$ is the pressure ratio at the same corrected flow on the surge line. Positive surge margin indicates stable operation; values above roughly 10–15% are typically considered acceptable for cruise in transport engines [2]. A larger value corresponds to a greater safety buffer to stall.

4.2. High–Pressure Compressor Map at Cruise

The off–design analysis used the CFM56–type engine design selected in HW2 ($\pi_c \approx 20$, $T_4 = 1650$ K) and switched to the Off–Design module in GasTurb. The baseline flight condition was set to an altitude of 11,000 m, $M_\infty = 0.80$, ISA atmosphere, and the high–pressure compressor (HPC) map was computed using 20 operating points along the control schedule. The resulting HPC map is shown in Fig. 3.

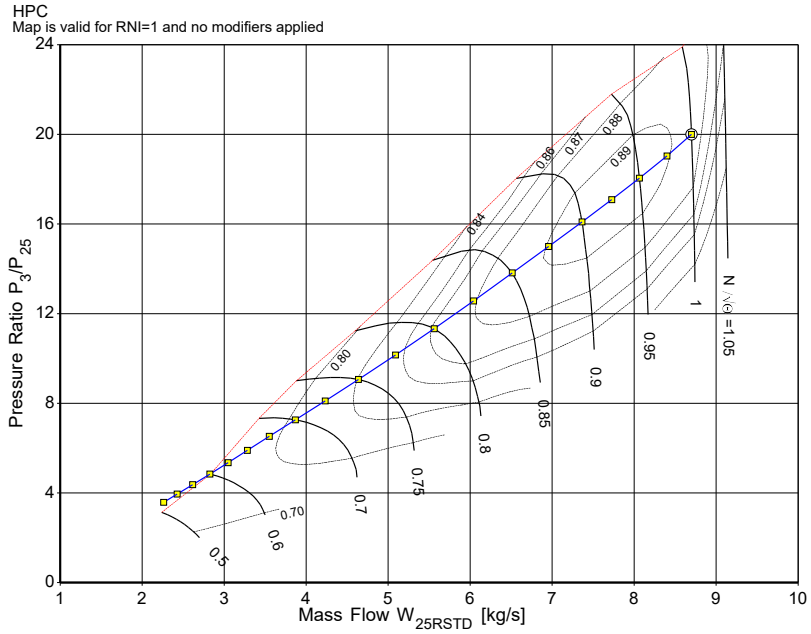


Fig. 3. High–pressure compressor map with operating line at $h = 11{,}000$ m and $M_\infty = 0.80$.

The map is plotted as total–pressure ratio P_3/P_{25} versus corrected inlet mass flow. The blue operating line moves from low corrected flow and pressure ratio at idle to higher flow and π_c as throttle is increased. It remains comfortably between the red surge boundary on the left and the high–flow choke limit on the right. Over most of the cruise range the operating line tracks near the peak–efficiency islands (polytropic efficiency $\eta_p \approx 0.87$–0.89), which is consistent with the HW2 result that the design point was chosen to give good TSFC at the nominal cruise condition.

4.3. Effect of Altitude on the HPC Operating Line

To see how ambient conditions shift the compressor operating line, the off–design calculation was repeated at a lower altitude of 8,000 m and a higher altitude of 14,000 m, keeping $M_\infty = 0.80$ and the same control schedule. The corresponding HPC maps are shown in Figs. 4 and 5.

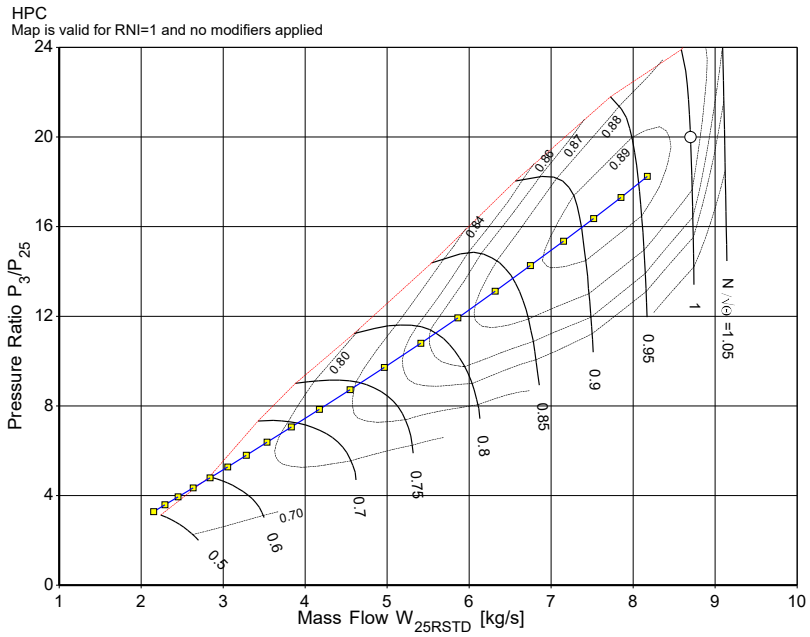


Fig. 4. High–pressure compressor map and operating line at $h = 8{,}000$ m, $M_\infty = 0.80$.

At the lower altitude (8,000 m), the higher ambient density increases the actual mass flow for a given corrected speed. This shifts the operating line to the right on the map, toward higher corrected flow, with a modest increase in pressure ratio at high power. The line still stays well away from the surge boundary, but the compressor operates slightly farther from the peak–efficiency islands as it is pushed toward the higher–flow side of the map.

At the higher altitude (14,000 m), the reduced ambient density lowers the mass flow, moving the operating line leftward toward lower corrected flow and slightly lower pressure ratio for the same spool speeds. The line comes somewhat closer to the surge boundary, especially at low throttle, but remains with a positive surge margin throughout the normal operating range. These shifts show how altitude changes alone move the compressor operating point across the map even when the control schedule is unchanged.

4.4. Surge Margin Versus HP Spool Speed

Finally, GasTurb's $y = f(x)$ plotting tool was used to quantify the stability margin as a function of HP spool speed at the 11,000 m cruise condition. The x–axis was set to the relative corrected HP spool speed and the y–axis to the HPC surge margin. The resulting curve is plotted in Fig. 6.

At very low spool speeds (relative corrected speed $N_{\text{corr}} \lesssim 0.6$) the curve dips below zero surge margin, indicating that those throttle settings would place the compressor to the left of the surge line and are therefore not operable. As the HP spool speed increases, the surge margin quickly

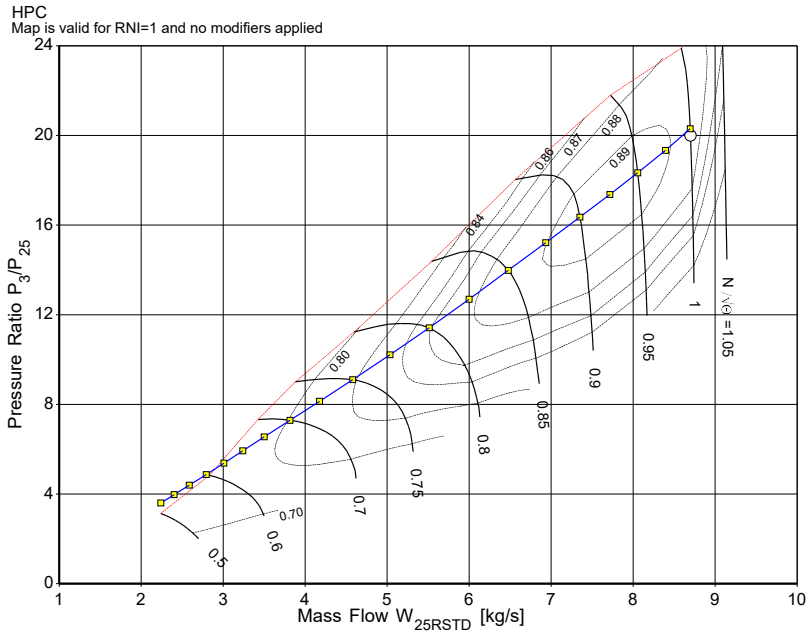


Fig. 5. High–pressure compressor map and operating line at h = 14,000 m, M_∞ = 0.80.

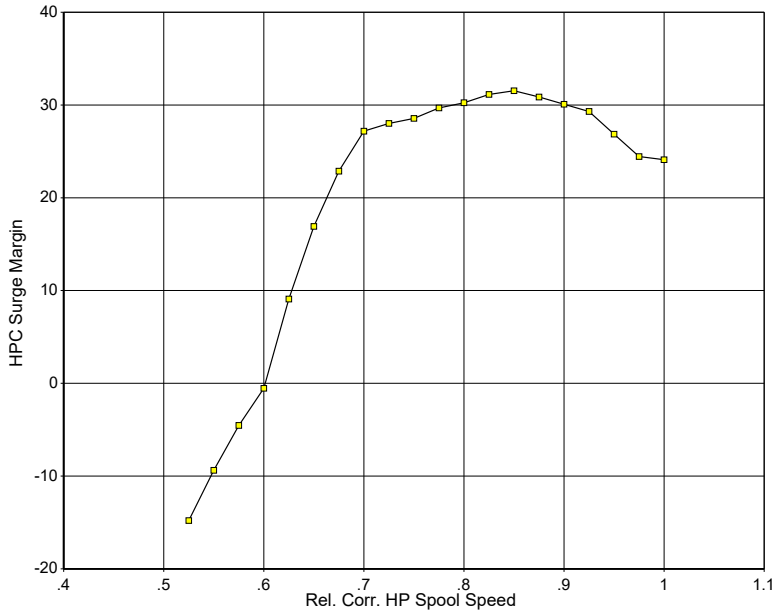


Fig. 6. HPC surge margin as a function of relative corrected HP spool speed at h = 11,000 m, M_∞ = 0.80.

becomes positive and rises to a broad maximum of roughly 30–33% near $N_{\mathrm{corr}} \approx 0.8$–$0.85$, which corresponds to the normal cruise setting. Beyond this point the margin decreases slowly as the operating line approaches the choke boundary at very high power.

Using the *Details* tool on the first operating–line point with positive surge margin, the minimum safe HP spool speed was found to be approximately $N_{\mathrm{HP,min}} \approx 1.6 \times 10^4$ rpm. At the design cruise point the HP spool runs at about 2.5×10^4 rpm, so the engine has a substantial buffer in both directions: it can throttle down to roughly 60% of the design HP spool speed before losing surge margin, and it can throttle up without approaching choke. The peak surge margin of about 30% is consistent with typical design targets for transport engines at cruise [2]. Overall, the HW3 maps and surge–margin curve confirm that the CFM56–type engine has robust compressor operability over the range of flight conditions considered.

5. Conclusions

This three–part project used GasTurb 14 to connect the hand analysis in AE 433 to more realistic gas–turbine performance modeling. In HW1, a two–spool unmixed–flow turbofan based on the HW9 cycle was recreated in GasTurb; the design–point station states matched the hand calculations in trend, while TSFC differed by about a factor of two due to more detailed component and property models. In HW2, a two–parameter design–space study in overall compressor pressure ratio and turbine inlet temperature at 11,000 m and $M_\infty = 0.80$ identified a broad valley of low TSFC, with a minimum of approximately 21 g/(kN s) near $\pi_c \approx 20$, $T_4 = 1650$ K. A specific design at this point was selected for further study. HW3 then showed that this design operates with healthy surge margin on the compressor maps over a range of cruise altitudes: the HPC surge margin remains positive for $N_{\mathrm{corr}} \gtrsim 0.6$, peaks at about 30–33% near the cruise corrected speed, and does not approach the surge boundary at either 8 km or 14 km. Overall, GasTurb provided a useful bridge between simple analytical cycle models and the more detailed performance tools used in industry, illustrating how design–point analysis, parametric trade studies, and off–design operability assessments fit into a coherent engine modeling workflow.

References

[1] Hill, P. G., and Peterson, C. R., *Mechanics and Thermodynamics of Propulsion*, 2nd ed., Addison-Wesley, Reading, MA, 1992.

[2] Mattingly, J. D., *Elements of Gas Turbine Propulsion*, McGraw-Hill, New York, 1996.

[3] Kurzke, J., *GasTurb 14: Design and Off-Design Performance of Gas Turbines*, GasTurb GmbH, Aachen, Germany, 2015. User's manual and software documentation.

[4] Instructor Lastname, B. S., "AE 433: Aircraft and Rocket Propulsion – Course Notes," Class handouts and online materials, University of Illinois at Urbana-Champaign, 2025. Accessed via course Canvas site.

[5] Instructor Lastname, B. S., "AE 433 GasTurb Project Overview and Homework Instructions," AE 433 project handout, University of Illinois at Urbana-Champaign, 2025. GasTurb project description for HW1–HW3.