Tabel General Parameter *Input Turbo-Prop Engine* PT6A-114A

Parameter	*Input*	Satuan
γ_c	1,4	-
C_{pc}	0,24	Btu/(lbm.°R)
γ_t	1,3	-
C_{pt}	0,276	Btu/(lbm.°R)
h_{PR}	18.400	Btu/lbm
π_{dmax}	0,97	-
π_b	0,90	-
π_d	0,98	-
π_b	0,96	-
π_n	0,99	-
π_t	0,46	-
π_c	7	-
g_c	32,174	ft.lbm/(lbf.s^2)
e_c	0,90	-
e_{tH}	0,89	-
e_{tL}	0,91	-
η_b	0,99	-
η_g	0,99	-
η_{mH}	0,99	-
η_{mL}	0,99	-
η_{prop}	0,83	-

Tabel 4.2 Parameter *Input Engine TBO* 3600 *hours*

Parameter	*Input*	Satuan
T_0	524,07	^{0}R
Tt_4	1.679,67	^{0}R

1. Perhitungan *performance* pada *TBO* (3.600 *hours*) pada ketinggian 4.500 *ft* berdasarkan data *aircraft flight log* yang di *record* pada 31 Oktober 2014. Tabel 4.1 merupakan parameter *input engine TBO* 3.600 *hours*.

Tabel 1.1 General Parameter *Input Turbo-Prop Engine* PT6A-114A

Parameter	*Input*	Satuan

γ_c	1,4	-
C_{pc}	0,24	Btu/(lbm.^oR)
γ_t	1,3	-
C_{pt}	0,276	Btu/(lbm.^oR)
h_{PR}	18.400	Btu/lbm
π_{dmax}	0,97	-
π_b	0,90	-
π_d	0,98	-
π_b	0,96	-
π_n	0,99	-
π_t	0,46	-
π_c	7	-
g_c	32,174	ft.lbm/(lbf.s^2)
e_c	0,90	-
e_{tH}	0,89	-
e_{tL}	0,91	-
η_b	0,99	-
η_g	0,99	-
η_{mH}	0,99	-
η_{mL}	0,99	-
η_{prop}	0,83	-

Tabel 1.2 Parameter *Input Engine TBO* 3600 *hours*

Parameter	*Input*	Satuan
T_0	524,07	^0R
Tt_4	1.679,67	^0R

Perhitungan:

1) Menghitung konstanta gas di kompresor:

$$R_c = \frac{\gamma_c - 1}{\gamma_c} C_{pc}$$

$R_c = konstanta\ kompresor$

$\gamma_c = Ratio\ Specific\ Heat\ Compressor,$ ketetapan nilai 1,4

$\gamma_c =$ ketetapan , nilai 1,4 $ref. Element\ of\ Gas\ Turbine\ Propulsion$

$C_{pc} = Specific\ \ heat\ compressor,$ ketetapan nilai $0{,}24\ BTU/lbm.°R$

$Ref. Element\ of\ Gas\ Turbine\ Propulsion, Jack\ D. Mattingly$

$$R_c = \frac{1{,}4 - 1}{1{,}4} 0{,}24$$

$R_c = 0{,}06857\ BTU/lbm.°R$

$R_c = 0{,}06857\ x\ 778{,}16\ ft.lbf/lbm.°R$

$R_c = 53{,}35954\ ft.lbf/lbm.°R$

2) Menghitung konstanta gas di t*urbine*:

$$R_t = \frac{\gamma_t - 1}{\gamma_t} C_{pt}$$

$R_t = konstanta\ turbine$

$\gamma_t = Ratio\ Specific\ Heat\ Turbine,$ ketetapan nilai 1,3

$Ref. Element\ of\ Gas\ Turbine\ Propulsion, Jack\ D. Mattingly$

$C_{pt} = Specific\ \ heat\ turbine,$ ketetapan nilai $0{,}276\ BTU/lbm.°R$

$Ref. Element\ of\ Gas\ Turbine\ Propulsion, Jack\ D. Mattingly$

$R_t = \frac{1{,}3-1}{1{,}3} 0{,}276\ = 0{,}63692$ *BTU/lbm.°R*

$R_t = 0{,}63692\ x\ 778{,}16\ \ ft.lbf/bm.°R$

$R_t = 49{,}56281\ \ ft.lbf/bm.°R$

3) Menghitung *Sound Speed* atau kecepatan suara:

$a_0 = \sqrt{\gamma_c\ R_c\ \ g_c\ T_0}$

$a_0 = Sound\ Speed$

$\gamma_c = Specific\ Heat\ Compressor\ Ratio,$ ketetapan nilai 1,4

$Ref. Element\ of\ Gas\ Turbine\ Propulsion, Jack\ D. Mattingly$

$R_c =$ konstanta gas di $turbine$

$=$ dari hasil perhitungan sebelumnya $53{,}35954\ (ft.lbf/lbm.°R)$

$g_c = \ Newton\ value$

$g_c = 1\ Newton = 3{,}2808\ ft/sec^2$

$$g_c = 3{,}2808\ x\ 9{,}806754\ \left(\frac{lbm}{lbf}\right) feet/sec^2$$

$g_c = 32{,}174\ feet.lbm/(lbf.sec^2)$

$T_0 = Ambient\ temperature\ in\ the\ flight\ (°R)$

Diketahui OAT = 18°C

OAT = (273,15+18)°K = 291,15K

OAT = $T_0 = 291{,}15\ x\ 1{,}8 = 524{,}07°R$

$a_0 = \sqrt{1{,}4 \text{ x } 53{,}35954\ x\ 32{,}174\ x\ 524{,}07}$

$a_0 = 1.122{,}321406\ ft/sec$

$a_0 = 1.122{,}321406/3{,}28\ meter/sec$

$a_0 = 342{,}17116\ meter/sec$

$$a_0 = 342{,}17116\ x \frac{3.600}{1.000} km/hr$$

$a_0 = 1.231{,}8161\ km/hr$

$karena\ 1\ knot = 1\ NM/hr$

$1\ NM = 1{,}852\ km$, maka

$a_0 = 1.231{,}8161/1{,}852\ NM/hr$

$a_0 = 665{,}1274\ NM/hr$

4) Menghitung *Absolute velocity*:

V_0= TAS=$(\frac{FL}{1.000} x\ 2\%\ x\ 0{,}98\ x\ IAS) + IAS$

V_0 = *Absolute Velocity*

TAS= *True Air Speed (knot)*

$FL = Flight\ level$ *or altitude* pada ketinggian terbang 4.500 *ft*

$IAS = Indicated\ Air\ Speed,$ sebesar 146 $knot$

V_0= $(\frac{4500}{1000} x\ 2\%\ x\ 0{,}98\ x\ 146) + 146$

V_0= $158{,}8772\ knot$

V_0= $158{,}8772\ NM/hr$

V_0= $158{,}8772\ x\ 1{,}852\ km/hr$

V_0= $294{,}24057\ km/hr$

V_0= $81{,}72643\ m/sec$

V_0= $81{,}72643\ x\ 3{,}2808 = 268{,}12808 ft/sec$

5) Menghitung *Ratio Temperature Ram*:

$\tau_r = 1 + \frac{\gamma_c - 1}{2} M_0^2$

$\tau_r = Ram\ Temperature\ Ratio$

$\gamma_c = Specific\ Heat\ Compressor\ Ratio,$ ketetapan nilai1,4

$Ref. Element\ of\ Gas\ Turbine\ Propulsion, Jack\ D. Mattingly$

$M_0 = Mach\ Number\ (Mach)$

$M_0 = V_0/a_0$

V_0 = *Absolute Velocity*

= dari hasil perhitungan sebelumnya sebesar 268,1281ft/sec

$a_0 = Sound\ Speed = 1.122{,}321376\ ft/sec$

= hasil perhitungan sebelumnya sebesar 1.122,321376 ft/sec

$M_0 = \frac{268{,}1281}{1122{,}321376} = 0{,}238905\ Mach$

$\tau_r = 1 + \frac{1{,}4 - 1}{2} 0{,}238905^2$

$\tau_r = 1{,}01142$

6) Menghitung *Ram Pressure Ratio*:

$\pi_r = \tau_r^{\gamma_c/\ (\gamma_c - 1)}$

$\pi_r = Ram\ Pressure\ Ratio$

$\tau_r = Ram\ Temperature\ Ratio$

= dari hasil perhitungan sebelumnya sebesar 1,01142

$\gamma_c = Specific\ Heat\ Compressor\ Ratio,$ ketetapan nilai 1,4

$Ref. Element\ of\ Gas\ Turbine\ Propulsion, Jack\ D. Mattingly$

$\pi_r = 1{,}011415^{1{,}4/\ (1{,}4-1)} = 1{,}04053$

7) Menghitung *Inlet Pressure Ratio:*

$\pi_d = \pi_{dmax}\ x\ \eta_r$

$\pi_d = Inlet\ Pressure\ Ratio$

$\pi_{dmax} = Maximum\ Difuser\ Pressure\ Ratio,$ ketetapan nilai 0,97

$Ref. Element\ of\ Gas\ Turbine\ Propulsion, Jack\ D. Mattingly$

$\eta_r = Ram\ Efficiency$

Dimana:

η_r= 1 untuk $M_0 \leq 1$

$\eta_r = 1 - 0{,}0075(M_0 - 1)^{1{,}35}$ untuk $M_0 \geq 1$

$\pi_d = 0{,}97\ x\ 1 = 0{,}97$

8) Menghitung *entalphy ratio* di ruang bakar dengan *ambient temperature* pada ketinggian terbang:

$$\tau_\lambda = \frac{C_{pt}\ x\ T_{t4}}{C_{pc} T_0}$$

$\tau_\lambda = Entalphy\ Ratio$

$C_{pt} = Specific\ Heat\ Turbine$, ketetapan nilai $0{,}276\ BTU/lbm.°R$

$Ref. Element\ of\ Gas\ Turbine\ Propulsion, Jack\ D. Mattingly$

$C_{pc} = Specific\ Heat\ Compressor$, ketetapan nilai $0{,}24\ BTU/lbm.°R$

$Ref. Element\ of\ Gas\ Turbine\ Propulsion, Jack\ D. Mattingly$

$T_{t4} = Inter\ Turbine\ Temperature$, sebesar $1.679{,}67\ °R$

$T_0 = Temperature\ Ambient$, sebesar $524{,}07\ °R$

$$\tau_\lambda = \frac{0{,}276\ x 1.679{,}67}{0{,}24\ x\ 524{,}07} = 3{,}68581$$

9) Menghitung *temperature ratio* di ruang bakar dengan *ambient temperature* pada ketinggian terbang :

$\tau_c = {\pi_c}^{(\gamma_c - 1)/\ (\gamma_c\ \varepsilon_c)}$

$\tau_c = Compressor\ Temperature\ Ratio$

$\pi_c = Compressor\ Total\ Pressure\ Ratio$, sebesar 7

$Ref. General\ Engine\ PT6A - 114A\ EMM\ 72 - 00 - 00$

$\gamma_c = Ratio\ Specific\ Heat\ Compressor$, ketetapan nilai 1,4

$Ref. Element\ of\ Gas\ Turbine\ Propulsion, Jack\ D. Mattingly$

$e_c = Polytropic\ Efficiency\ Compressor$, ketetapan nilai 0,90

$Ref. Element\ of\ Gas\ Turbine\ Propulsion, Jack\ D. Mattingly$

$\tau_c = 7^{(1,4-1)/\,(1,4\,x\,0,90)} = 1,85475$

10) Menghitung *Compressor Efficiency*:

$$\eta_c = \frac{\pi_c{}^{(\gamma_c-1)/\gamma_c} - 1}{\tau_c - 1}$$

$\eta_c = Compressor\ Efficiency$

$\pi_c = Compressor\ Total\ Pressure\ Ratio,$ ketetapan nilai 7

$Ref.General\ Engine\ PT6A - 114A\ EMM\ 72 - 00 - 00$

$\gamma_c = Specific\ Heat\ Compressor\ Ratio,$ ketetapan nilai 1,4

$Ref.Element\ of\ Gas\ Turbine\ Propulsion, Jack\ D.Mattingly$

$\tau_c = Compressor\ Temperature\ Ratio$

= dari hasil perhitungan sebelumnya sebesar 1,85475

$$\eta_c = \frac{7^{(1,4-1)/1,4} - 1}{1,854748 - 1} = 0,87001$$

11) Menghitung *Fuel/Air Ratio:*

$$f = \frac{\tau_\lambda - \tau_r\tau_c}{\eta_b h_{PR}/(C_{pc}T_0) - \tau_\lambda}$$

$f = Fuel/Air\ Ratio$

$\tau_\lambda = Entalphy\ Ratio$

= dari hasil perhitungan sebelumnya sebesar 3,68581

$\tau_r = Ram\ Temperature\ Ratio$

= dari hasil perhitungan sebelumnya sebesar 1,01142

$\tau_c = Compressor\ Temperature\ Ratio$

= dari hasil perhitungan sebelumnya sebesar 1,85475

$\eta_b = Blade\ Efficiency,$ ketetapan nilai 0,99

Ref. Element of Propulsion Engine, Jack D. Mattingly

$h_{PR} = Low\ Heating\ Value\ Fuel,$ ketetapan nilai 18.400 BTU/lbm

Ref. Element of Propulsion Engine, Jack D. Mattingly

$C_{pc} = Specific\ Heat\ Compressor,$ ketetapan nilai 0,24 $BTU/lbm.°R$

Ref. Element of Propulsion Engine, Jack D. Mattingly

$T_0 = Temperature\ Ambient,$ sebesar 524,07 $°R$

$$f = \frac{3{,}68581 - 1{,}01142\ x\ 1{,}85475}{0{,}99\ x\ 18.400/(0{,}24\ x\ 524{,}07) - 3{,}68581} = 0{,}01282$$

12) Menghitung *High Temperature Turbine*:

$$\tau_{tH} = 1 - \frac{\tau_r(\tau_c - 1)}{\eta_{mH}(1+f)\tau_\lambda}$$

$\tau_{tH} = High\ Turbine\ Temperature\ Ratio$

$\tau_r = Ram\ Temperature\ Ratio2$

$=$ dari hasil perhitungan sebelumnya sebesar 1,01141

$\tau_c = Compressor\ Temperature\ Ratio$

$=$ dari hasil perhitungan sebelumnya sebesar 1,85475

$\eta_{mH} = High\ Pressure\ Mass\ Flow\ Efficiency,$ ketetapan nilai 0,99

$Ref.\ Element\ of\ Gas\ Turbine\ Propulsion, Jack\ D.\ Mattingly$

$f = Fuel/Air\ Ratio$

$=$ dari hasil perhitungan sebelumnya sebesar 0,01282

$\tau_\lambda = Entalphy\ Ratio$

$=$ dari hasil perhitungan sebelumnya sebesar 3,68581

$$\tau_{tH} = 1 - \frac{1{,}01142(1{,}85475 - 1)}{0{,}99(1 + 0{,}01282)3{,}68581} = 0{,}76608$$

13) Menghitung *Turbine High Temperature Ratio*:

$$\pi_{tH} = \tau_{tH}^{\gamma_t/[(\gamma_t - 1)e_{tH}]}$$

$\pi_{tH} = High\ Turbine\ Total\ Pressure\ Ratio$

$\tau_{tH} = High\ Turbine\ Temperature\ Ratio$

$=$ dari hasil perhitungan sebelumnya sebesar 0,76608

$\gamma_t = Ratio\ Specific\ Heat\ Turbine,$ ketetapan nilai 1,3

$Ref.\ Element\ of\ Gas\ Turbine\ Propulsion, Jack\ D.\ Mattingly$

$e_{tH} = Polytropic\ Efficiency\ High\ Pressure\ Turbine,$ nilai 0,89

$Ref.\ Element\ of\ Gas\ Turbine\ Propulsion, Jack\ D.\ Mattingly$

$$\pi_{tH} = 0{,}76608^{\frac{1{,}3}{(1{,}3-1)0{,}89}} = 0{,}27324$$

14) Menghitung *Turbine Low Temperature Ratio*:

$$\tau_{tLi}^{*} = \frac{\tau_{tH}^{-1/e_{tH}}}{\pi} + A$$

Dimana

$$\pi = (\pi_r \pi_d \pi_c \pi_b \pi_n)^{(\gamma_t - 1)/\gamma_t}$$

dan

$$A = \frac{\left[\frac{\gamma_c - 1}{2}\right]\left[\frac{M_0^2}{(\tau_\lambda \tau_{tH})}\right]}{(\eta_{prop}\eta_g\eta_{mL})^2}$$

$\pi = Pressure$

$\pi_r = Ram\ Pressure\ Ratio$

$=$ dari hasil perhitungan sebelumnya sebesar 1,04053

$\pi_d = Inlet\ Pressure\ Ratio,$ ketetapan nilai 0,97

$Ref.\ Element\ of\ Gas\ Turbine\ Propulsion, Jack\ D.\ Mattingly$

$\pi_c = Compressor\ Total\ Pressure\ Ratio,$ nilai 7

$Ref.\ General\ Engine\ PT6A - 114A\ EMM\ 72 - 00 - 00$

$\pi_b = Burner\ Total\ Pressure\ Ratio,$ ketetapan nilai 0,96

$Ref.\ Element\ of\ Gas\ Turbine\ Propulsion, Jack\ D.\ Mattingly$

$\pi_n = Nozzle\ Total\ Pressure\ Ratio,$ ketetapan nilai 0,99

$Ref.\ Element\ of\ Gas\ Turbine\ Propulsion, Jack\ D.\ Mattingly$

$\gamma_t = Ratio\ Specific\ Heat\ Turbine,$ ketetapan nilai 1,3

$Ref.\ Element\ of\ Gas\ Turbine\ Propulsion, Jack\ D.\ Mattingly$

$A = Area$

$\gamma_c = Specific\ Heat\ Compressor\ Ratio,$ ketetapan nilai 1,4

$Ref.\ Element\ of\ Gas\ Turbine\ Propulsion, Jack\ D.\ Mattingly$

$M_0 = Mach\ Number$

$=$ dari hasil perhitungan sebelumnya sebesar 0,238905 $Mach$

$\tau_\lambda = Entalphy\ Ratio$

$=$ dari hasil perhitungan sebelumnya sebesar 3,68581

$\tau_{tH} = High\,Turbine\,Temperature\,Ratio$

$=$ dari hasil perhitungan sebelumnya sebesar 0,76608

$\eta_{prop} = Efficiency\,Propeller,$ ketetapan nilai 0,83

$Ref.\,Element\,of\,Gas\,Turbine\,Propulsion, Jack\,D.\,Mattingly$

$\eta_g = Efficiency\,Gas,$ ketetapan nilai 0,99

$Ref.\,Element\,of\,Gas\,Turbine\,Propulsion, Jack\,D.\,Mattingly$

$\eta_{mL} = Low\,Pressure\,Mass\,Flow\,Efficiency,$ ketetapan nilai 0,99

$Ref.\,Element\,of\,Gas\,Turbine\,Propulsion, Jack\,D.\,Mattingly$

Dengan substitusi data yang ada didapatkan hasil perhitungan sebagai berikut

$$\pi = (1{,}04053\ x\ 0{,}97\ x\ 7\ x\ 0{,}96\ x\ 0{,}99)^{(1{,}3-1)/\,1{,}3} = 1{,}55186$$

dan

$$A = \frac{\left[\frac{1{,}4-1}{2}\right]\left[\frac{0{,}238905^2}{(3{,}68581\ x\ 0{,}76608)}\right]}{(0{,}83x\ 0{,}99\ x\ 0{,}99)^2} = 4{,}043x\ 10^{-3}$$

Selanjutnya nilai τ_{tLi}^* dilakukan iterasi sampai nilainya mendekati 0,0001.

$$\tau_{tLi}^* = \frac{0{,}76608^{-1/0{,}89}}{1{,}55186} + 4{,}043x\ 10^{-3} = 0{,}87336$$

$$\tau_{tLx} = \frac{\tau_{tH}^{-1/e_{tH}}}{\pi}\tau_{tLi}^{-(1-e_{tL})/e_{tL}} + A(1 + \frac{1-e_{tL}}{e_{tL}}\frac{\tau_{tH}^{-1/e_{tH}}\ \tau_{tL}^{-1/e_{tL}}}{\pi})^2$$

$$\tau_{tLx} = \frac{0{,}76608^{-1/0{,}89}}{1{,}55186}0{,}87336^{-(1/0{,}91)/0{,}91} +$$

$$4{,}043x\ 10^{-3}(1 + \frac{1-0{,}91}{0{,}91}\frac{0{,}76608^{-1/0{,}89}x\ 0{,}87336^{-1/0{,}91}}{1{,}55186})^2$$

$$\tau_{tLx} = 0{,}8859$$

$$\tau_{tLxx} = \frac{\tau_{tH}^{-1/e_{tH}}}{\pi}\tau_{tLx}^{-(1-e_{tL})/e_{tL}} + A(1 + \frac{1-e_{tL}}{e_{tL}}\frac{\tau_{tH}^{-1/e_{tH}}\ \tau_{tLx}^{-1/e_{tL}}}{\pi})^2$$

$$\tau_{tLxx} = \frac{0{,}76608^{-1/0{,}89}}{1{,}55186}0{,}8859^{-(1/0{,}91)/0{,}91} +$$

$$4{,}043x\ 10^{-3}(1+\frac{1-0{,}91}{0{,}91}\frac{0{,}76608^{-1/0{,}89}x\ 0{,}8859^{-1/0{,}91}}{1{,}55186})^2$$

$\tau_{tLxx} = 0{,}8847$

$$\tau_{tLxxx} = \frac{\tau_{tH}^{-1/e_{tH}}}{\pi}\tau_{tLxx}^{-(1-e_{tL})/e_{tL}} + A(1+\frac{1-e_{tL}}{e_{tL}}\frac{\tau_{tH}^{-1/e_{tH}}\ \tau_{tLxx}^{-1/e_{tL}}}{\pi})^2$$

$$\tau_{tLxxx} = \frac{0{,}76608^{-1/0{,}89}}{1{,}55186}0{,}8847^{-(1/0{,}91)/0{,}91} +$$

$$4{,}043x\ 10^{-3}(1+\frac{1-0{,}91}{0{,}91}\frac{0{,}76608^{-1/0{,}89}x\ 0{,}8847^{-1/0{,}91}}{1{,}55186})^2$$

$\tau_{tLxxx} = 0{,}8848$

$\tau_{tLxx} - \tau_{tLxxx} = 0{,}8847 - 0{,}8848 = 0{,}0001$ telah terpenuhi iterasi.

Sehingga nilai *Turbine Low Temperature Ratio* (τ_{tLi}^{*}) sebesar 0,8848

15) Menghitung *Turbine Low Pressure Ratio*:

$$\pi_{tL} = \tau_{tL}^{\gamma\frac{t}{\gamma_t - 1 e_{tL}}}$$

$\pi_{tL} = Low\ Turbine\ Total\ Pressure\ Ratio$

$\tau_{tL} = Low\ Turbine\ Temperature\ Ratio$

= dari hasil perhitungan sebelumnya sebesar 0,8848

$\gamma_t = Ratio\ Specific\ Heat\ Turbine,$ ketetapan nilai 1,3

$Ref.\ Element\ of\ Gas\ Turbine\ Propulsion, Jack\ D.\ Mattingly$

$e_{tL} = Polytropic\ Efficiency\ Low\ Pressure\ Turbine,$ nilai 0,91

$Ref.\ Element\ of\ Gas\ Turbine\ Propulsion, Jack\ D.\ Mattingly$

$$\pi_{tL} = 0{,}8848^{\frac{1{,}3}{(1{,}3-1)0{,}91}} = 0{,}55829$$

16) Menghitung *Ratio Total Pressure dan Overall Pressure*:

$$\frac{P_{t9}}{P_0} = \pi_r\pi_d\pi_c\pi_b\pi_{tH}\pi_{tL}\pi_n$$

$$\frac{P_{t9}}{P_0} = Ratio\ Total\ Pressure\ and\ Overall\ Pressure$$

$\pi_r = Ram\ Pressure\ Ratio$

$= $ dari hasil perhitungan sebelumnya sebesar 1,04053

$\pi_d = Inlet\ Pressure\ Ratio,$ ketetapan nilai 0,97

$Ref. Element\ of\ Gas\ Turbine\ Propulsion, Jack\ D. Mattingly$

$\pi_c = Compressor\ Total\ Pressure\ Ratio,$ nilai 7

$Ref. General\ Engine\ PT6A - 114A\ EMM\ 72 - 00 - 00$

$\pi_b = Burner\ Total\ Pressure\ Ratio,$ ketetapan nilai 0,96

$Ref. Element\ of\ Gas\ Turbine\ Propulsion, Jack\ D. Mattingly$

$\pi_{tH} = High\ Turbine\ Total\ Pressure\ Ratio$

$= $ dari hasil perhitungan sebelumnya sebesar 0,27324

$\pi_{tL} = Low\ Turbine\ Total\ Pressure\ Ratio$

$= $ dari hasil perhitungan sebelumnya sebesar 0,55829

$\pi_n = Nozzle\ Total\ Pressure\ Ratio,$ ketetapan nilai 0,99

$Ref. Element\ of\ Gas\ Turbine\ Propulsion, Jack\ D. Mattingly$

$$\frac{P_{t9}}{P_0} = 1{,}04053\ x\ 0{,}97\ x\ 7\ x\ 0{,}96\ x\ 0{,}27324\ x\ 0{,}55829 x\ 0{,}99$$

$$\frac{P_{t9}}{P_0} = 1{,}0243$$

$$\gamma_t = Ratio\ Specific\ Heat\ Turbine = 1{,}3$$

$$\frac{P_{t9}}{P_9} = \left(\frac{\gamma_t + 1}{2}\right)^{\gamma_t/(\gamma_t - 1)}$$

$$\frac{P_{t9}}{P_9} = \left(\frac{1{,}3 + 1}{2}\right)^{1{,}3/(1{,}3-1)} = 1{,}83242$$

$$\frac{P_0}{P_9} = \frac{\frac{P_{t9}}{P_9}}{\frac{P_{t9}}{P_0}} = \frac{1{,}83242}{1{,}0243} = 1{,}78894$$

17) Menghitung rasio kecepatan aliran udara di *nozzle* dan *Sound Speed*:

$$\frac{V_9}{a_0} = \sqrt{\frac{2\tau_\lambda \tau_{tH} \tau_{tL}}{\gamma_c - 1}[1 - \left(\frac{P_{t9}}{P_9}\right)^{-(\gamma_t - 1)/\gamma_t}]}$$

$\frac{V_9}{a_0} = Rasio$ kecepatan aliran udara di nozzle dan $sound\ speed$

$\tau_\lambda = Entalphy\ Ratio$

= dari hasil perhitungan sebelumnya sebesar 3,68581

$\tau_{tH} = High\ Turbine\ Temperature\ Ratio$

= dari hasil perhitungan sebelumnya sebesar 0,76608

$\tau_{tL} = Low\ Turbine\ Temperature\ Ratio$

= dari hasil perhitungan sebelumnya sebesar 0,8848

$\gamma_c = Specific\ Heat\ Compressor\ Ratio$, ketetapan nilai 1,4

$Ref. Element\ of\ Gas\ Turbine\ Propulsion, Jack\ D. Mattingly$

$\gamma_t = Ratio\ Specific\ Heat\ Turbine$, ketetapan nilai 1,3

$Ref. Element\ of\ Gas\ Turbine\ Propulsion, Jack\ D. Mattingly$

$$\frac{V_9}{a_0} = \sqrt{\frac{2\ x\ 3,68581\ x\ 0,76608\ x\ 0,8848}{1,4-1}[1-(1,83242)^{-(1,3-1)/1,3}]}$$

$$\frac{V_9}{a_0} = 1,27645$$

18) Menghitung Koefisien Kerja *Output Propeller*:

$C_{prop} = \eta_{prop}\eta_g\eta_{mL}(1+f)\tau_\lambda\tau_{tH}(1-\tau_{tL})$

$\eta_{prop} = Efficiency\ Propeller$, ketetapan nilai 0,83

$Ref. Element\ of\ Gas\ Turbine\ Propulsion, Jack\ D. Mattingly$

$\eta_g = Efficiency\ Gas\ Turbine$, ketetapan nilai 0,99

$Ref. Element\ of\ Gas\ Turbine\ Propulsion, Jack\ D. Mattingly$

$\eta_{mL} = Low\ Pressure\ Mass\ Flow\ Efficiency$, ketetapan nilai0,99

$Ref. Element\ of\ Gas\ Turbine\ Propulsion, Jack\ D. Mattingly$

$f = Fuel/Air\ Ratio$

= dari hasil perhitungan sebelumnya sebesar 0,01282

$\tau_\lambda = Entalphy\ Ratio$

= dari hasil perhitungan sebelumnya sebesar 3,68581

$\tau_{tH} = High\ Turbine\ Temperature\ Ratio$

= dari hasil perhitungan sebelumnya sebesar 0,76608

$\tau_{tL} = Low\ Turbine\ Temperature\ Ratio$

$= \text{dari hasil perhitungan sebelumnya sebesar } 0{,}8848$

$C_{prop} = 0{,}83\ x\ 0{,}99\ x\ 0{,}99 x\ (1 + 0{,}01282) 3{,}68581 x\ 0{,}76608 (1 - 0{,}8848)$

$C_{prop} = 0{,}26539$

19) Menghitung Koefisien Kerja *Compressor Core:*

$$C_c = (\gamma_c - 1) M_0 [(1+f) \frac{V_9}{a_0} - M_0 + (1+f) \frac{R_t}{R_c} \frac{\frac{T_9}{T_0}}{\frac{V_9}{a_0}} - \frac{1 - \frac{P_0}{P_9}}{\gamma_c}$$

$C_c = \text{Koefisien kerja } output\ core$

$\gamma_c = Specific\ Heat\ Compressor\ Ratio, \text{ketetapan nilai } 1{,}4$

$Ref. Element\ of\ Gas\ Turbine\ Propulsion, Jack\ D. Mattingly$

$M_0 = Mach\ Number$

$= \text{dari hasil perhitungan sebelumnya sebesar } 0{,}238905\ Mach$

$\frac{V_9}{a_0} = Rasio\ aliran\ udara\ di\ nozzle\ dan\ sound\ speed = 1{,}27645$

$= \text{dari hasil perhitungan sebelumnya sebesar } 1{,}27645$

$f = Fuel/Air\ Ratio$

$= \text{dari hasil perhitungan sebelumnya sebesar } 0{,}01282$

$R_t = Konstanta\ Turbine$

$= \text{dari perhitungan sebelumnya sebesar } 49{,}56281\ \ ft. lbf/bm. °R$

$R_c =\ Konstanta\ Kompresor$

$= \text{dari perhitungan sebelumnya sebesar } 53{,}35954\ ft. lbf/lbm. °R$

$\frac{T_{t9}}{T_0} = \frac{T_{t4}}{T_0} \tau_{tH} \tau_{tL}$

$T_{t4} = Interturbine\ Temperature, \text{sebesar } 1.679{,}07\ °R$

$T_0 = Temperature\ Ambient, \text{sebesar } 524{,}07\ °R$

$\tau_{tH} = High\ Turbine\ Temperature\ Ratio$

$= \text{dari perhitungan sebelumnya sebesar } 0{,}76608$

$\tau_{tL} = Low\ Turbine\ Temperature\ Ratio$

$= \text{dari perhitungan sebelumnya sebesar } 0{,}8848$

$\frac{P_0}{P_9} = 1{,}78894$

$\frac{T_{t9}}{T_0} = \frac{1.679{,}67}{524{,}07} 0{,}76608\ x\ 0{,}8848 = 2{,}17245$

$\frac{T_9}{T_0} = \frac{\frac{T_{t9}}{T_0}}{\left(\frac{P_{t9}}{P_9}\right)^{(\gamma_t - 1)/\gamma_t}} = \frac{2{,}17245}{(1{,}83242)^{(1{,}3-1)/1{,}3}} = 1{,}88908$

$C_c = (1{,}4 - 1)0{,}238905[(1 + 0{,}01282)1{,}27645 - 0{,}238905$
$+ (1 + 0{,}01282)\frac{49{,}56281}{53{,}35954}\frac{1{,}88908}{1{,}27645} - \frac{1 - 1{,}78894}{1{,}4}$

$C_c = 0{,}02574$

20) Menghitung koefisien kerja *output* pada *engine core total:*

$C_{tot} = C_{prop} + C_c$

C_{tot} = koefisien kerja *output* pada *engine core total*

C_{prop} = Koefisien Kerja *Output Propeller*

= dari hasil perhitungan sebelumnya sebesar 0,26539

C_c = Koefisien kerja *output core*

= dari hasil perhitungan sebelumnya sebesar 0,02574

$C_{tot} = 0{,}26539 + 0{,}02574$

$C_{tot} = 0{,}29113$

21) Menghitung *Thrust and Mass Flow Ratio*:

$\frac{F}{\dot{m}_0} = \frac{C_{tot} C_{pc} T_0}{V_0}$

$\frac{F}{\dot{m}_0}$ = *Specific Thrust*

C_{tot} = koefisien kerja *output* pada *engine core total*

= dari hasil perhitungan sebelumnya sebesar 0,29113

C_{pc} = *Specific heat compressor*, nilai 0,24 $BTU/lbm.°R$

Ref. Element of Gas Turbine Propulsion, Jack D. Mattingly

T_0 = *Temperature Ambient*, sebesar 524,07 °R

V_0 = *Absolute Velocity*

$= \text{dari hasil perhitungan sebelumnya sebesar } 268{,}1281\ ft/sec$

$$\frac{F}{\dot{m}_0} = \frac{0{,}29113\ x\ 0{,}24\ x\ 524{,}07}{268{,}1281}$$

$$\frac{F}{\dot{m}_0} = 179{,}34758\ lbf/(lbm/sec)$$

22) Menghitung *Specific Fuel Consumption:*

$$S = \frac{f}{F/_{\dot{m}_0}}$$

$f = Fuel/Air\ Ratio$

$= \text{dari hasil perhitungan sebelumnya sebesar } 0{,}01282$

$$\frac{F}{\dot{m}_0} = Specific\ Thrust$$

$= \text{dari hasil perhitungan sebesar } 179{,}34758\ lbf/(lbm/sec)$

$$S = \frac{0{,}01282\ x\ 3600}{179{,}34758} = 0{,}2574\ (lbm/hr)/lbf$$

23) Menghitung *Specific Power*:

$$\frac{\dot{W}}{\dot{m}_0} = C_{tot} C_{pc} T_0$$

$$\frac{\dot{W}}{\dot{m}_0} = Specific\ Power$$

C_{tot} = koefisien kerja *output* pada *engine core total*

$= \text{dari hasil perhitungan sebelumnya sebesar } 0{,}29113$

$C_{pc} = Specific\ \ heat\ compressor$, nilai 0,24 $BTU/lbm.°R$

$Ref. Element\ of\ Gas\ Turbine\ Propulsion, Jack\ D. Mattingly$

$T_0 = Temperature\ Ambient$, sebesar 524,07 $°R$

$$\frac{\dot{W}}{\dot{m}_0} = 0{,}29113\ x\ 0{,}24\ x\ 524{,}07$$

$$\frac{\dot{W}}{\dot{m}_0} = 36{,}61746\ hp/(lbm/sec)$$

24) Menghitung *Efficiency Thermal*, *Propulsive*, *Overall*

$$\eta T = \frac{C_{tot}}{\frac{f\ x\ hPR}{C_{pc} x\ T_0}}$$

$$\eta P = \frac{C_{tot}}{\left(\frac{C_{prop}}{\eta_{prop}}\right) + \left(\frac{\gamma_c - 1}{2}\right) x\ (1 + f) x\ [\left(\frac{V_9}{a_0}\right)^2 - M_0^2]}$$

$$\eta O = \eta T\ x\ \eta P$$

maka diperoleh:

$$\eta T = \frac{0{,}29113}{\frac{0{,}01282\ x\ 18.400}{0{,}276 x 524{,}07}} = 15{,}5\%$$

$$\eta P = \frac{0{,}29113}{\left(\frac{0{,}26539}{0{,}83}\right) + \left(\frac{1{,}4 - 1}{2}\right) x\ (1 + 0{,}01282) x\ [(1{,}27645)^2 - 0{,}238905^2]}$$

$$\eta P = 45{,}6\%$$

$$\eta O = 15{,}5\%\ x\ 45{,}6\% = 7{,}1\%$$

2. Perhitungan *performance* pada *TBO* (3.600 *hours*) pada ketinggian 5.500 *ft* berdasarkan data *aircraft flight log* yang di *record* di. Tabel 1.3 merupakan parameter *input engine TBO* 3.600 *hours*.

Tabel 1.3 Parameter *Input Engine TBO* 3600 *hours*

Parameter	*Input*	Satuan
T_0	527,27	^{0}R
Tt_4	1.706,67	^{0}R

Perhitungan:

1) Menghitung konstanta gas di kompresor:

$$R_c = \frac{\gamma_c - 1}{\gamma_c} C_{pc}$$

$$R_c = \frac{1,4 - 1}{1,4} 0,24$$

$$R_c = 0,06857\ BTU/lbm.°R$$

$$R_c = 0,06857\ x\ 778,16\ ft.lbf/lbm.°R$$

$$R_c = 53,35954\ ft.lbf/lbm.°R$$

2) Menghitung konstanta gas di t*urbine*:

$$R_t = \frac{\gamma_t - 1}{\gamma_t} C_{pt}$$

$$R_t = \frac{1,3-1}{1,3} 0,276 = 0,63692\ BTU/lbm.°R$$

$$R_t = 0,63692\ x\ 778,16\ \ ft.lbf/bm.°R$$

$$R_t = 49,56281\ \ ft.lbf/bm.°R$$

3) Menghitung *Sound Speed* atau kecepatan suara:

$$a_0 = \sqrt{\gamma_c\ R_c\ \ g_c\ T_0}$$

$$a_0 = \sqrt{1,4\ \text{x}\ \ 53,35954\ x\ 32,174\ x\ 524,07}$$

$$a_0 = 1.126,1696\ ft/sec$$

4) Menghitung *Absolute velocity*:

V_0= TAS=$(\frac{FL}{1.000} x\ 2\%\ x\ 0,98\ x\ IAS) + IAS$

V_0= $(\frac{5500}{1000} x\ 2\%\ x\ 0,98\ x\ 144) + 144$

V_0= $159,532\ knot$

V_0= $159,532\ NM/hr$

V_0= $159,532\ x\ 1,852\ km/hr$

V_0= $295,453264\ km/hr$

V_0= $82,07035\ m/sec$

V_0= $82.07035\ x\ 3,2808 = 269,2183 ft/sec$

5) Menghitung $Ratio\ Temperature\ Ram$:

$$\tau_r = 1 + \frac{\gamma_c - 1}{2} M_0^2$$

$dimana$:

$M_0 = V_0/a_0$

$M_0 = \frac{269,2183}{1126,1696} = 0,239057\ Mach$

$$\tau_r = 1 + \frac{1,4 - 1}{2} 0,239057^2$$

$\tau_r = 1,01143$

6) Menghitung $Ram\ Pressure\ Ratio$:

   $\pi_r = {\tau_r}^{\gamma_c/\ (\gamma_c - 1)}$

   $\pi_r = 1,01143^{1,4/\ (1,4-1)} = 1,04058$

7) Menghitung *Inlet Pressure Ratio:*

   $\pi_d = \pi_{dmax}\ x\ \eta_r$

   Dimana:

   η_r= 1 untuk $M_0 \leq 1$

   $\eta_r = 1 - 0,0075(M_0 - 1)^{1,35}$ untuk $M_0 \geq 1$

   $\pi_d = 0,97\ x\ 1 = 0,97$

8) Menghitung *entalphy ratio* di ruang bakar dengan *ambient temperature* pada ketinggian terbang:

   $$\tau_\lambda = \frac{C_{pt}\ x\ T_{t4}}{C_{pc}T_0}$$

   $$\tau_\lambda = \frac{0,276\ x 1.706,67}{0,24\ x\ 527,07} = 3,7195$$

9) Menghitung *temperature ratio* di ruang bakar dengan *ambient temperature* pada ketinggian terbang :

   $\tau_c = {\pi_c}^{(\gamma_c - 1)/\ (\gamma_c\ \varepsilon_c)}$

   $\tau_c = 7^{(1,4-1)/\ (1,4\ x\ 0,90)} = 1,85475$

10) Menghitung *Compressor Efficiency*:

$$\eta_c = \frac{{\pi_c}^{(\gamma_c-1)/\gamma_c} - 1}{\tau_c - 1}$$

$$\eta_c = \frac{7^{(1{,}4-1)/1{,}4} - 1}{1{,}854748 - 1} = 0{,}87001$$

11) Menghitung *Fuel/Air Ratio:*

$$f = \frac{\tau_\lambda - \tau_r\tau_c}{\eta_b h_{PR}/(C_{pc}T_0) - \tau_\lambda}$$

$$f = \frac{3{,}7195 - 1{,}01143\ x\ 1{,}85475}{0{,}99\ x\ 18.400/(0{,}24\ x\ 527{,}67) - 3{,}7195} = 0{,}01316$$

12) Menghitung *High Temperature Turbine*:

$$\tau_{tH} = 1 - \frac{\tau_r(\tau_c - 1)}{\eta_{mH}(1+f)\tau_\lambda}$$

$$\tau_{tH} = 1 - \frac{1{,}01143(1{,}85475 - 1)}{0{,}99(1 + 0{,}01316)3{,}7195} = 0{,}76827$$

13) Menghitung *Turbine High Temperature Ratio*:

$$\pi_{tH} = \tau_{tH}^{\gamma_t/[(\gamma_t-1)e_{tH}]}$$

$$\pi_{tH} = 0{,}76827^{\frac{1{,}3}{(1{,}3-1)0{,}89}} = 0{,}27707$$

14) Menghitung *Turbine Low Temperature Ratio*:

$$\tau_{tLi}^{*} = \frac{\tau_{tH}^{-1/e_{tH}}}{\pi} + A$$

Dimana

$$\pi = (\pi_r\pi_d\pi_c\pi_b\pi_n)^{(\gamma_t-1)/\gamma_t}$$

dan

$$A = \frac{\left[\frac{\gamma_c - 1}{2}\right]\left[\frac{M_0^2}{(\tau_\lambda\,\tau_{tH})}\right]}{(\eta_{prop}\eta_g\eta_{mL})^2}$$

$$\pi = (1{,}04058\ x\ 0{,}97\ x\ 7\ x\ 0{,}96\ x\ 0{,}99)^{(1{,}3-1)/\,1{,}3} = 1{,}55188$$

dan

$$A = \frac{\left[\frac{1,4-1}{2}\right]\left[\frac{0,239057^2}{(3,7195\ x\ 0,76827)}\right]}{(0,83x\ 0,99\ x\ 0,99)^2} = 4\ x\ 10^{-3}$$

Selanjutnya nilai τ_{tLi}^{*} dilakukan iterasi sampai nilainya mendekati 0,0001.

$$\tau_{tLi}^{*} = \frac{0,76827^{-1/0,89}}{1,55188} + 4\ x\ 10^{-3} = 0,87052$$

$$\tau_{tLx} = \frac{\tau_{tH}^{-1/e_{tH}}}{\pi}\tau_{tLi}^{-(1-e_{tL})/e_{tL}} + A(1 + \frac{1-e_{tL}}{e_{tL}}\frac{\tau_{tH}^{-1/e_{tH}}\ \tau_{tL}^{-1/e_{tL}}}{\pi})^2$$

$$\tau_{tLx} = \frac{0,76827^{-1/0,89}}{1,55188}0,87052^{-(1/0,91)/0,91} +$$

$$4\ x\ 10^{-3}(1 + \frac{1-0,91}{0,91}\frac{0,76827^{-1/0,89}x\ 087052^{-1/0,91}}{1,55188})^2$$

$$\tau_{tLx} = 0,88332$$

$$\tau_{tLxx} = \frac{\tau_{tH}^{-1/e_{tH}}}{\pi}\tau_{tLx}^{-(1-e_{tL})/e_{tL}} + A(1 + \frac{1-e_{tL}}{e_{tL}}\frac{\tau_{tH}^{-1/e_{tH}}\ \tau_{tLx}^{-1/e_{tL}}}{\pi})^2$$

$$\tau_{tLxx} = \frac{0,76827^{-1/0,89}}{1,55188}0,88332^{-(1/0,91)/0,91} +$$

$$4\ x\ 10^{-3}(1 + \frac{1-0,91}{0,91}\frac{0,76827^{-1/0,89}x\ 0,88332^{-1/0,91}}{1,55188})^2$$

$$\tau_{tLxx} = 0,88204$$

$$\tau_{tLxxx} = \frac{\tau_{tH}^{-1/e_{tH}}}{\pi}\tau_{tLxx}^{-(1-e_{tL})/e_{tL}} + A(1 + \frac{1-e_{tL}}{e_{tL}}\frac{\tau_{tH}^{-1/e_{tH}}\ \tau_{tLxx}^{-1/e_{tL}}}{\pi})^2$$

$$\tau_{tLxxx} = \frac{0,76827^{-1/0,89}}{1,55188}0,88204^{-(1/0,91)/0,91} +$$

$$4\ x\ 10^{-3}(1 + \frac{1-0,91}{0,91}\frac{0,76827^{-1/0,89}x\ 0,88204}{1,55188})^2$$

$$\tau_{tLxxx} = 0,88217$$

$\tau_{tLxxx} - \tau_{tLxx} = 0,88217 - 0,88204 = 0,00013$ telah terpenuhi iterasi.

Sehingga nilai *Turbine Low Temperature Ratio* (τ^*_{tLi}) sebesar 0,88217

15) Menghitung *Turbine Low Pressure Ratio*:

$$\pi_{tL} = \tau_{tL}^{\frac{\gamma_t}{\gamma_t - 1 e_{tL}}}$$

$$\pi_{tL} = 0{,}88217^{\frac{1{,}3}{(1{,}3-1)0{,}91}} = 0{,}55044$$

16) Menghitung *Ratio Total Pressure dan Overall Pressure*:

$$\frac{P_{t9}}{P_0} = \pi_r \pi_d \pi_c \pi_b \pi_{tH} \pi_{tL} \pi_n$$

$$\frac{P_{t9}}{P_0} = 1{,}04058\ x\ 0{,}97\ x\ 7\ x\ 0{,}96\ x\ 0{,}27707\ x\ 0{,}55044 x\ 0{,}99$$

$$\frac{P_{t9}}{P_0} = 1{,}02412$$

17) Menghitung rasio kecepatan aliran udara di *nozzle* dan *Sound Speed*:

$$\frac{V_9}{a_0} = \sqrt{\frac{2\tau_\lambda \tau_{tH} \tau_{tL}}{\gamma_c - 1}[1 - \left(\frac{P_{t9}}{P_9}\right)^{-(\gamma_t - 1)/\gamma_t}]}$$

$dimana$:

$$\frac{P_{t9}}{P_9} = \left(\frac{\gamma_t + 1}{2}\right)^{\gamma_{t/(\gamma_t - 1)}}$$

Maka:

$$\frac{P_{t9}}{P_9} = \left(\frac{1{,}3 + 1}{2}\right)^{1{,}3/(1{,}3-1)} = 1{,}83242$$

$$\frac{P_0}{P_9} = \frac{\frac{P_{t9}}{P_9}}{\frac{P_{t9}}{P_0}} = \frac{1{,}83242}{1{,}02412} = 1{,}78927$$

Sehingga:

$$\frac{V_9}{a_0} = \sqrt{\frac{2\ x\ 3{,}7195\ x\ 0{,}76827\ x\ 0{,}88217}{1{,}4 - 1}[1 - (1{,}83242)^{-(1{,}3-1)/1{,}3}]}$$

$$\frac{V_9}{a_0} = 1{,}2822$$

18) Menghitung Koefisien Kerja *Output Propeller*:

$$C_{prop} = \eta_{prop}\eta_g\eta_{mL}(1+f)\tau_\lambda\tau_{tH}(1-\tau_{tL})$$

$$C_{prop} = 0{,}83\ x\ 0{,}99\ x\ 0{,}99x\ (1+0{,}01316)3{,}7195x0{,}76827(1-0{,}88217)$$

$$C_{prop} = 0{,}27752$$

19) Menghitung Koefisien Kerja *Compressor Core:*

$$C_c = (\gamma_c - 1)M_0[(1+f)\frac{V_9}{a_0} - M_0 + (1+f)\frac{R_t}{R_c}\frac{\frac{T_9}{T_0}}{\frac{V_9}{a_0}} - \frac{1-\frac{P_0}{P_9}}{\gamma_c}$$

$dimana$:

$$\frac{T_9}{T_0} = \frac{\frac{T_{t9}}{T_0}}{\left(\frac{P_{t9}}{P_9}\right)^{(\gamma_t-1)/\gamma_t}}$$

dan

$$\frac{T_{t9}}{T_0} = \frac{T_{t4}}{T_0}\tau_{tH}\tau_{tL}$$

$$\frac{T_{t9}}{T_0} = \frac{1.706{,}67}{527{,}67}0{,}88217\ x\ 0{,}88217 = 2{,}19206$$

Maka:

$$\frac{T_9}{T_0} = \frac{2{,}19206}{(1{,}83242)^{(1{,}3-1)/1{,}3}} = 1{,}90614$$

Sehingga:

$$C_c = (1{,}4-1)0{,}239057[(1+0{,}01316)1{,}2822 - 0{,}239057 + (1+0{,}01316)\frac{49{,}56281}{53{,}35954}\frac{1{,}90614}{1{,}2822} - \frac{1-1{,}78927}{1{,}4}$$

$$C_c = 0{,}02594$$

20) Menghitung koefisien kerja *output* pada *engine core total:*

$C_{tot} = C_{prop} + C_c$

$C_{tot} = 0{,}27752 + 0{,}02594$

$C_{tot} = 0{,}30347$

21) Menghitung *Thrust and Mass Flow Ratio*:

$$\frac{F}{\dot{m}_0} = \frac{C_{tot} C_{pc} T_0}{V_0}$$

$$\frac{F}{\dot{m}_0} = \frac{0{,}30347 \ x\ 0{,}24 \ x\ 527{,}27}{269{,}2183}$$

$$\frac{F}{\dot{m}_0} = 187{,}46922 \ lbf/(lbm/sec)$$

22) Menghitung *Specific Fuel Consumption:*

$$S = \frac{f}{F/\dot{m}_0}$$

$$S = \frac{0{,}01316 \ x\ 3600}{187{,}46922} = 0{,}25265 \ (lbm/hr)/lbf$$

23) Menghitung *Specific Power*:

$$\frac{\dot{W}}{\dot{m}_0} = C_{tot} C_{pc} T_0$$

$$\frac{\dot{W}}{\dot{m}_0} = 0{,}30347 \ x\ 0{,}24 \ x\ 527{,}27$$

$$\frac{\dot{W}}{\dot{m}_0} = 38{,}43129 \ hp/(lbm/sec)$$

24) Menghitung *Efficiency Thermal*, *Propulsive*, *Overall*

$$\eta T = \frac{0{,}30347}{\frac{0{,}01316 \ x\ 18.400}{0{,}276 x 527{,}07}} = 15{,}9\%$$

$$\eta P = \frac{0{,}30347}{\left(\frac{0{,}27752}{0{,}83}\right) + \left(\frac{1{,}4-1}{2}\right) x\ (1+0{,}01316) x\ [(1{,}2822)^2 - 0{,}239057^2]}$$

$\eta P = 46{,}3\%$

$\eta O = 15{,}9\%\ x\ 46{,}3\% = 7{,}4\%$

3. Perhitungan *performance* pada *TBO* (3.600 *hours*) pada ketinggian 5.500 *ft* berdasarkan data *aircraft flight log* yang di *record* di Tabel 1.4 merupakan parameter *input engine TBO* 3.600 *hours*.

Tabel 1.4 Parameter *Input Engine TBO* 3600 *hours*

Parameter	*Input*	Satuan
T_0	524,07	^{0}R
Tt_4	1.715,67	^{0}R

Perhitungan:

1) Menghitung konstanta gas di kompresor:

$$R_c = \frac{\gamma_c - 1}{\gamma_c} C_{pc}$$

$$R_c = \frac{1{,}4 - 1}{1{,}4} 0{,}24$$

$$R_c = 0{,}06857\ BTU/lbm.°R$$

$$R_c = 0{,}06857\ x\ 778{,}16\ ft.lbf/lbm.°R$$

$$R_c = 53{,}35954\ ft.lbf/lbm.°R$$

2) Menghitung konstanta gas di t*urbine*:

$$R_t = \frac{\gamma_t - 1}{\gamma_t} C_{pt}$$

$$R_t = \frac{1{,}3-1}{1{,}3} 0{,}276 = 0{,}63692\ BTU/lbm.°R$$

$$R_t = 0{,}63692\ x\ 778{,}16\ \ ft.lbf/bm.°R$$

$$R_t = 49{,}56281\ \ ft.lbf/bm.°R$$

3) Menghitung *Sound Speed* atau kecepatan suara:

$$a_0 = \sqrt{\gamma_c\ R_c\ \ g_c\ T_0}$$

$a_0 = \sqrt{1{,}4 \text{ x } 53{,}35954\ x\ 32{,}174\ x\ 524{,}07}$

$a_0 = 1.122{,}32141 ft/sec$

4) Menghitung *Absolute velocity*:

V_0= TAS=$(\frac{FL}{1.000} x\ 2\%\ x\ 0{,}98\ x\ IAS) + IAS$

V_0= $(\frac{6500}{1000} x\ 2\%\ x\ 0{,}98\ x\ 141) + 141$

V_0= $158{,}963\ knot$

V_0= $158{,}963\ NM/hr$

V_0= $158{,}963\ x\ 1{,}852\ km/hr$

V_0= $294{,}39947\ km/hr$

V_0= $81{,}77763\ m/sec$

V_0= $81{,}77763\ x\ 3{,}2808 = 268{,}2736\ ft/sec$

5) Menghitung *Ratio Temperature Ram*:

$\tau_r = 1 + \frac{\gamma_c - 1}{2} M_0^2$

dimana:

$M_0 = V_0/a_0$

$M_0 = \frac{268{,}27}{1.122{,}32141} = 0{,}239035\ Mach$

$\tau_r = 1 + \frac{1{,}4 - 1}{2} 0{,}239035^{\ 2}$

$\tau_r = 1{,}01143$

6) Menghitung *Ram Pressure Ratio*:

$\pi_r = \tau_r^{\gamma_c/\ (\gamma_c - 1)}$

$\pi_r = 1{,}01143^{1{,}4/\ (1{,}4-1)} = 1{,}04057$

7) Menghitung *Inlet Pressure Ratio:*

$\pi_d = \pi_{dmax}\ x\ \eta_r$

Dimana:

η_r= 1 untuk $M_0 \leq 1$

$\eta_r = 1 - 0{,}0075(M_0 - 1)^{1{,}35}$ untuk $M_0 \geq 1$

$\pi_d = 0{,}97\ x\ 1 = 0{,}97$

8) Menghitung *entalphy ratio* di ruang bakar dengan *ambient temperature* pada ketinggian terbang:

$$\tau_\lambda = \frac{C_{pt}\ x\ T_{t4}}{C_{pc}T_0}$$

$$\tau_\lambda = \frac{0{,}276\ x 1.715{,}67}{0{,}24\ x\ 524{,}07} = 3{,}7648$$

9) Menghitung *temperature ratio* di ruang bakar dengan *ambient temperature* pada ketinggian terbang :

$$\tau_c = \pi_c{}^{(\gamma_c - 1)/\ (\gamma_c\ \varepsilon_c)}$$

$$\tau_c = 7^{(1{,}4-1)/\ (1{,}4\ x\ 0{,}90)} = 1{,}85475$$

10) Menghitung *Compressor Efficiency*:

$$\eta_c = \frac{\pi_c{}^{(\gamma_c - 1)/\gamma_c} - 1}{\tau_c - 1}$$

$$\eta_c = \frac{7^{(1{,}4-1)/1{,}4} - 1}{1{,}854748 - 1} = 0{,}87001$$

11) Menghitung *Fuel/Air Ratio:*

$$f = \frac{\tau_\lambda - \tau_r\tau_c}{\eta_b h_{PR}/(C_{pc}T_0) - \tau_\lambda}$$

$$f = \frac{3{,}7648 - 1{,}01143\ x\ 1{,}85475}{0{,}99\ x\ 18.400/(0{,}24\ x\ 524{,}07) - 3{,}7648} = 0{,}01339$$

12) Menghitung *High Temperature Turbine*:

$$\tau_{tH} = 1 - \frac{\tau_r(\tau_c - 1)}{\eta_{mH}(1+f)\tau_\lambda}$$

$$\tau_{tH} = 1 - \frac{1{,}01143(1{,}85475 - 1)}{0{,}99(1 + 0{,}01339)3{,}7648} = 0{,}77111$$

13) Menghitung *Turbine High Temperature Ratio*:

$$\pi_{tH} = \tau_{tH}^{\gamma_t/[(\gamma_t-1)e_{tH}]}$$

$$\pi_{tH} = 0{,}77111^{\frac{1{,}3}{(1{,}3-1)0{,}89}} = 0{,}28209$$

14) Menghitung *Turbine Low Temperature Ratio*:

$$\tau_{tLi}^{*} = \frac{\tau_{tH}^{-1/e_{tH}}}{\pi} + A$$

Dimana

$$\pi = (\pi_r\pi_d\pi_c\pi_b\pi_n)^{(\gamma_t-1)/\,\gamma_t}$$

dan

$$A = \frac{\left[\frac{\gamma_c - 1}{2}\right]\left[\frac{M_0^2}{(\tau_\lambda\,\tau_{tH})}\right]}{(\eta_{prop}\eta_g\eta_{mL})^2}$$

$maka$:

$$\pi = (1{,}04057x\ 0{,}97\ x\ 7\ x\ 0{,}96\ x\ 0{,}99)^{(1{,}3-1)/\,1{,}3} = 1{,}55188$$

dan

$$A = \frac{\left[\frac{1{,}4-1}{2}\right]\left[\frac{0{,}239035^2}{(3{,}7648\ x\ 0{,}77111)}\right]}{(0{,}83x\ 0{,}99\ x\ 0{,}99)^2} = 3{,}94\ x\ 10^{-3}$$

Selanjutnya nilai τ_{tLi}^{*} dilakukan iterasi sampai nilainya mendekati 0,0001.

$$\tau_{tLi}^{*} = \frac{0{,}77111^{-1/0{,}89}}{1{,}55188} + 3{,}94\ x\ 10^{-3} = 0{,}86687$$

$$\tau_{tLx} = \frac{\tau_{tH}^{-1/e_{tH}}}{\pi}\tau_{tLi}^{-(1-e_{tL})/e_{tL}} + A(1 + \frac{1-e_{tL}}{e_{tL}}\frac{\tau_{tH}^{-1/e_{tH}}\ \tau_{tLi}^{-1/e_{tL}}}{\pi})^2$$

$$\tau_{tLx} = \frac{0{,}77111^{-1/0{,}89}}{1{,}55188} 0{,}86687^{-(1/0{,}91)/0{,}91} +$$

$$3{,}94\ x\ 10^{-3}(1 + \frac{1-0{,}91}{0{,}91}\frac{0{,}77111^{-1/0{,}89} x\ 0{,}86687^{-1/0{,}91}}{1{,}55188})^2$$

$$\tau_{tLx} = 0{,}879972$$

$$\tau_{tLxx} = \frac{\tau_{tH}^{-1/e_{tH}}}{\pi} \tau_{tLx}^{-(1-e_{tL})/e_{tL}} + A(1 + \frac{1-e_{tL}}{e_{tL}}\frac{\tau_{tH}^{-1/e_{tH}}\ \tau_{tLx}^{-1/e_{tL}}}{\pi})^2$$

$$\tau_{tLxx} = \frac{0{,}77111^{-1/0{,}89}}{1{,}55188} 0{,}879972^{-(1/0{,}91)/0{,}91} +$$

$$3{,}94\ x\ 10^{-3}(1 + \frac{1-0{,}91}{0{,}91}\frac{0{,}77111^{-1/0{,}89} x\ 0{,}879972^{-1/0{,}91}}{1{,}55188})^2$$

$$\tau_{tLxx} = 0{,}87866$$

$$\tau_{tLxxx} = \frac{\tau_{tH}^{-1/e_{tH}}}{\pi} \tau_{tLxx}^{-(1-e_{tL})/e_{tL}} + A(1 + \frac{1-e_{tL}}{e_{tL}}\frac{\tau_{tH}^{-1/e_{tH}}\ \tau_{tLxx}^{-1/e_{tL}}}{\pi})^2$$

$$\tau_{tLxxx} = \frac{0{,}77111^{-1/0{,}89}}{1{,}55188} 0{,}87866^{-(1/0{,}91)/0{,}91} +$$

$$3{,}94\ x\ 10^{-3}(1 + \frac{1-0{,}91}{0{,}91}\frac{0{,}77111^{-1/0{,}89} x\ 0{,}87866^{-1/0{,}91}}{1{,}55188})^2$$

$$\tau_{tLxxx} = 0{,}87879$$

$\tau_{tLxxx} - \tau_{tLxx} = 0{,}87879 - 0{,}87866 = 0{,}00013$ telah terpenuhi iterasi.

Sehingga nilai *Turbine Low Temperature Ratio* (τ_{tLi}^*) sebesar 0,87879

15) Menghitung *Turbine Low Pressure Ratio*:

$$\pi_{tL} = \tau_{tL}^{\frac{\gamma_t}{\gamma_t - 1 e_{tL}}}$$

$$\pi_{tL} = 0{,}87879^{\frac{1{,}3}{(1{,}3-1)0{,}91}} = 0{,}54049$$

16) Menghitung *Ratio Total Pressure dan Overall Pressure*:

$$\frac{P_{t9}}{P_0} = \pi_r \pi_d \pi_c \pi_b \pi_{tH} \pi_{tL} \pi_n$$

$$\frac{P_{t9}}{P_0} = 1{,}04057\ x\ 0{,}97\ x\ 7\ x\ 0{,}96\ x\ 0{,}28209\ x\ 0{,}54049\ x\ 0{,}99$$

$$\frac{P_{t9}}{P_0} = 1{,}02382$$

17) Menghitung rasio kecepatan aliran udara di *nozzle* dan *Sound Speed*:

$$\frac{V_9}{a_0} = \sqrt{\frac{2\tau_\lambda \tau_{tH} \tau_{tL}}{\gamma_c - 1}[1 - \left(\frac{P_{t9}}{P_9}\right)^{-(\gamma_t - 1)/\gamma_t}]}$$

$dimana$:

$$\frac{P_{t9}}{P_9} = \left(\frac{\gamma_t + 1}{2}\right)^{\gamma_{t/(\gamma_t - 1)}}$$

Maka:

$$\frac{P_{t9}}{P_9} = \left(\frac{1{,}3 + 1}{2}\right)^{1{,}3/(1{,}3-1)} = 1{,}83242$$

$$\frac{P_0}{P_9} = \frac{\frac{P_{t9}}{P_9}}{\frac{P_{t9}}{P_0}} = \frac{1{,}83242}{1{,}02382} = 1{,}78978$$

Sehingga:

$$\frac{V_9}{a_0} = \sqrt{\frac{2\ x\ 3{,}7648\ x\ 0{,}77111\ x\ 0{,}87879}{1{,}4 - 1}[1 - (1{,}83242)^{-(1{,}3-1)/1{,}3}]}$$

$$\frac{V_9}{a_0} = 1{,}2899$$

18) Menghitung Koefisien Kerja *Output Propeller*:

$$C_{prop} = \eta_{prop}\eta_g\eta_{mL}(1 + f)\tau_\lambda \tau_{tH}(1 - \tau_{tL})$$

$$C_{prop} = 0{,}83x\ 0{,}99\ x\ 0{,}99x\ (1 + 0{,}01339)3{,}7648x0{,}77111(1 - 0{,}87879)$$

$$C_{prop} = 0{,}29008$$

19) Menghitung Koefisien Kerja *Compressor Core:*

$$C_c = (\gamma_c - 1)M_0[(1+f)\frac{V_9}{a_0} - M_0 + (1+f)\frac{R_t}{R_c}\frac{\frac{T_9}{T_0}}{\frac{V_9}{a_0}} - \frac{1 - \frac{P_0}{P_9}}{\gamma_c}$$

$dimana$:

$$\frac{T_9}{T_0} = \frac{\frac{T_{t9}}{T_0}}{\left(\frac{P_{t9}}{P_9}\right)^{(\gamma_t - 1)/\gamma_t}}$$

dan

$$\frac{T_{t9}}{T_0} = \frac{T_{t4}}{T_0}\tau_{tH}\tau_{tL}$$

$$\frac{T_{t9}}{T_0} = \frac{1.715,67}{524,07} 0,77111 \; x \; 0,8787 = 2,1844$$

Maka:

$$\frac{T_9}{T_0} = \frac{2,1844}{(1,83242)^{(1,3-1)/1,3}} = 1,92908$$

Sehingga:

$$C_c = (1,4 - 1)0,239035 \; [(1 + 0,01339)1,2899 - 0,239035 + (1 + 0,01339)\frac{49,56281}{53,35954}\frac{1,92908}{1,2899} - \frac{1 - 1,78978}{1,4}$$

$$C_c = 0,0262$$

20) Menghitung koefisien kerja *output* pada *engine core total:*

$$C_{tot} = C_{prop} + C_c$$

$$C_{tot} = 0,29008 + 0,0262$$

$$C_{tot} = 0,31628$$

21) Menghitung *Thrust and Mass Flow Ratio*:

$$\frac{F}{\dot{m}_0} = \frac{C_{tot}C_{pc}T_0}{V_0}$$

$$\frac{F}{\dot{m}_0} = \frac{0,31628 \; x \; 0,24 \; x \; 524,07}{268,2736}$$

$$\frac{F}{\dot{m}_0} = 194{,}73638\ lbf/(lbm/sec)$$

22) Menghitung *Specific Fuel Consumption:*

$$S = \frac{f}{F/\dot{m}_0}$$

$$S = \frac{0{,}01339\ x\ 3600}{194{,}73638} = 0{,}24754\ (lbm/hr)/lbf$$

23) Menghitung *Specific Power*:

$$\frac{\dot{W}}{\dot{m}_0} = C_{tot} C_{pc} T_0$$

$$\frac{\dot{W}}{\dot{m}_0} = 0{,}31628 x\ 0{,}24\ x\ 524{,}07$$

$$\frac{\dot{W}}{\dot{m}_0} = 39{,}78097\ hp/(lbm/sec)$$

24) Menghitung *Efficiency Thermal*, *Propulsive*, *Overall*

$$\eta T = \frac{0{,}31628}{\frac{0{,}01339\ x\ 18.400}{0{,}276 x 524{,}07}} = 16{,}1\%$$

$$\eta P = \frac{0{,}31628}{\left(\frac{0{,}29008}{0{,}83}\right) + \left(\frac{1{,}4-1}{2}\right) x\ (1 + 0{,}01339) x\ [(1{,}2899)^2 - 0{,}239035^2]}$$

$$\eta P = 46{,}8\%$$

$$\eta O = 16{,}1\%\ x\ 46{,}8\% = 7{,}5\%$$

4. Perhitungan *performance* pada *TBO* (3.600 *hours*) pada ketinggian 7.500 *ft* berdasarkan data *aircraft flight log*. Tabel 1.5 merupakan parameter *input engine TBO* 3.600 *hours*.

Tabel 1.5 Parameter *Input Engine TBO* 3600 *hours*

Parameter	*Input*	Satuan
T_0	520,47	^{0}R
Tt_4	1.715,67	^{0}R

Perhitungan:

1) Menghitung konstanta gas di kompresor:

$$R_c = \frac{\gamma_c - 1}{\gamma_c} C_{pc}$$

$$R_c = \frac{1{,}4 - 1}{1{,}4} 0{,}24$$

$$R_c = 0{,}06857\ BTU/lbm.°R$$

$$R_c = 0{,}06857\ x\ 778{,}16\ ft.lbf/lbm.°R$$

$$R_c = 53{,}35954\ ft.lbf/lbm.°R$$

2) Menghitung konstanta gas di t*urbine*:

$$R_t = \frac{\gamma_t - 1}{\gamma_t} C_{pt}$$

$$R_t = \frac{1{,}3-1}{1{,}3} 0{,}276 = 0{,}63692\ BTU/lbm.°R$$

$$R_t = 0{,}63692\ x\ 778{,}16\ ft.lbf/bm.°R$$

$$R_t = 49{,}56281\ ft.lbf/bm.°R$$

3) Menghitung *Sound Speed* atau kecepatan suara:

$$a_0 = \sqrt{\gamma_c\ R_c\ g_c\ T_0}$$

$$a_0 = \sqrt{1{,}4\ \text{x}\ 53{,}35954\ x\ 32{,}174\ x\ 520{,}47}$$

$$a_0 = 1.118{,}35954\ ft/sec$$

4) Menghitung *Absolute velocity*:

$$V_0 = \text{TAS} = \left(\frac{FL}{1.000}\ x\ 2\%\ x\ 0{,}98\ x\ IAS\right) + IAS$$

$$V_0 = \left(\frac{7500}{1000}\ x\ 2\%\ x\ 0{,}98\ x\ 140\right) + 140$$

$$V_0 = 160{,}58\ knot$$

$$V_0 = 160{,}58\ NM/hr$$

$V_0 = 160{,}58\ x\ 1{,}852\ km/hr$

$V_0 = 297{,}394\ km/hr$

$V_0 = 82{,}609\ m/sec$

$V_0 = 82{,}609\ x\ 3{,}2808 = 271{,}0018\ ft/sec$

5) Menghitung *Ratio Temperature Ram*:

$$\tau_r = 1 + \frac{\gamma_c - 1}{2} M_0^2$$

dimana:

$$M_0 = V_0/a_0$$

$$M_0 = \frac{271{,}0018}{1.118{,}35954} = 0{,}242299\ Mach$$

$$\tau_r = 1 + \frac{1{,}4 - 1}{2} 0{,}242299^{\ 2}$$

$$\tau_r = 1{,}012$$

6) Menghitung *Ram Pressure Ratio*:

$$\pi_r = \tau_r^{\gamma_c/\ (\gamma_c - 1)}$$

$$\pi_r = 1{,}012^{1{,}4/\ (1{,}4-1)} = 1{,}042$$

7) Menghitung *Inlet Pressure Ratio:*

$$\pi_d = \pi_{dmax}\ x\ \eta_r$$

Dimana:

$\eta_r = 1$ untuk $M_0 \leq 1$

$\eta_r = 1 - 0{,}0075(M_0 - 1)^{1{,}35}$ untuk $M_0 \geq 1$

$$\pi_d = 0{,}97\ x\ 1 = 0{,}97$$

8) Menghitung *entalphy ratio* di ruang bakar dengan *ambient temperature* pada ketinggian terbang:

$$\tau_\lambda = \frac{C_{pt}\ x\ T_{t4}}{C_{pc} T_0}$$

$$\tau_\lambda = \frac{0,276\ x 1.715,67}{0,24\ x\ 520,47} = 3,769084$$

9) Menghitung *temperature ratio* di ruang bakar dengan *ambient temperature* pada ketinggian terbang :

$$\tau_c = \pi_c^{(\gamma_c - 1)/\ (\gamma_c\ \varepsilon_c)}$$

$$\tau_c = 7^{(1,4-1)/\ (1,4\ x\ 0,90)} = 1,85475$$

10) Menghitung *Compressor Efficiency*:

$$\eta_c = \frac{\pi_c^{(\gamma_c - 1)/\gamma_c} - 1}{\tau_c - 1}$$

$$\eta_c = \frac{7^{(1,4-1)/1,4} - 1}{1,85475 - 1} = 0,87001$$

11) Menghitung *Fuel/Air Ratio:*

$$f = \frac{\tau_\lambda - \tau_r \tau_c}{\eta_b h_{PR}/(C_{pc} T_0) - \tau_\lambda}$$

$$f = \frac{3,769084 - 1,012\ x\ 1,85475}{0,99\ x\ 18.400/(0,24\ x\ 520,47) - 3,769084} = 0,01348$$

12) Menghitung *High Temperature Turbine*:

$$\tau_{tH} = 1 - \frac{\tau_r(\tau_c - 1)}{\eta_{mH}(1 + f)\tau_\lambda}$$

$$\tau_{tH} = 1 - \frac{1,012\ (1,85475 - 1)}{0,99(1 + 0,01348)3,769084} = 0,773$$

13) Menghitung *Turbine High Temperature Ratio*:

$$\pi_{tH} = \tau_{tH}^{\gamma_{t/[(\gamma_t - 1)e_{tH}]}}$$

$$\pi_{tH} = 0,773^{\frac{1,3}{(1,3-1)0,89}} = 0,285$$

14) Menghitung *Turbine Low Temperature Ratio*:

$$\tau_{tLi}^{*} = \frac{\tau_{tH}^{-1/e_{tH}}}{\pi} + A$$

Dimana

$$\pi = (\pi_r \pi_d \pi_c \pi_b \pi_n)^{(\gamma_t - 1)/\,\gamma_t}$$

dan

$$A = \frac{\left[\frac{\gamma_c - 1}{2}\right]\left[\frac{M_0^2}{(\tau_\lambda\, \tau_{tH})}\right]}{(\eta_{prop}\eta_g\eta_{mL})^2}$$

$maka$:

$$\pi = (1{,}042\ x\ 0{,}97\ x\ 7\ x\ 0{,}96\ x\ 0{,}99)^{(1{,}3-1)/\,1{,}3} = 1{,}552$$

dan

$$A = \frac{\left[\frac{1{,}4 - 1}{2}\right]\left[\frac{0{,}242299\ ^2}{(3{,}769084\ x\ 0{,}773)}\right]}{(0{,}83x\ 0{,}99\ x\ 0{,}99)^2} = 4{,}009\ x\ 10^{-3}$$

Selanjutnya nilai τ_{tLi}^{*} dilakukan iterasi sampai nilainya mendekati 0,0001.

$$\tau_{tLi}^{*} = \frac{0{,}773^{-1/0{,}89}}{1{,}5523} + 4{,}009\ x\ 10^{-3} = 0{,}8648$$

$$\tau_{tLx} = \frac{\tau_{tH}^{-1/e_{tH}}}{\pi}\tau_{tLi}^{-(1-e_{tL})/e_{tL}} + A(1 + \frac{1 - e_{tL}}{e_{tL}}\frac{\tau_{tH}^{-1/e_{tH}}\ \tau_{tLi}^{-1/e_{tL}}}{\pi})^2$$

$$\tau_{tLx} = \frac{0{,}773^{-1/0{,}89}}{1{,}5523} 0{,}8648^{-(1/0{,}91)/0{,}91} +$$

$$4{,}009\ x\ 10^{-3}(1 + \frac{1 - 0{,}91}{0{,}91}\frac{0{,}773^{-1/0{,}89}x\ 0{,}8648^{-1/0{,}91}}{1{,}5523})^2$$

$$\tau_{tLx} = 0{,}8781$$

$$\tau_{tLxx} = \frac{\tau_{tH}^{-1/e_{tH}}}{\pi}\tau_{tLx}^{-(1-e_{tL})/e_{tL}} + A(1 + \frac{1 - e_{tL}}{e_{tL}}\frac{\tau_{tH}^{-1/e_{tH}}\ \tau_{tLx}^{-1/e_{tL}}}{\pi})^2$$

$$\tau_{tLxx} = \frac{0{,}773^{-1/0{,}89}}{1{,}5523} 0{,}8781^{-(1/0{,}91)/0{,}91} +$$

$$4{,}009\ x\ 10^{-3}(1 + \frac{1 - 0{,}91}{0{,}91}\frac{0{,}773^{-1/0{,}89}x\ 0{,}8781^{-1/0{,}91}}{1{,}5523})^2$$

$$\tau_{tLxx} = 0{,}8768$$

$$\tau_{tLxxx} = \frac{\tau_{tH}^{-1/e_{tH}}}{\pi}\tau_{tLxx}^{-(1-e_{tL})/e_{tL}} + A(1 + \frac{1-e_{tL}}{e_{tL}}\frac{\tau_{tH}^{-1/e_{tH}}\ \tau_{tLxx}^{-1/e_{tL}}}{\pi})^2$$

$$\tau_{tLxxx} = \frac{0{,}773^{-1/0{,}89}}{1{,}5523}0{,}8768^{-(1/0{,}91)/0{,}91} +$$

$$4{,}009\ x\ 10^{-3}(1 + \frac{1-0{,}91}{0{,}91}\frac{0{,}773^{-1/0{,}89}x\ 0{,}8768^{-1/0{,}91}}{1{,}5523})^2$$

$$\tau_{tLxxx} = 0{,}8769$$

$\tau_{tLxxx} - \tau_{tLxx} = 0{,}8769 - 0{,}8768 = 0{,}0001$ telah terpenuhi iterasi.

Sehingga nilai *Turbine Low Temperature Ratio* (τ_{tLi}^{*}) sebesar 0,8769

15) Menghitung *Turbine Low Pressure Ratio*:

$$\pi_{tL} = \tau_{tL}^{\frac{\gamma_t}{\gamma_t - 1 e_{tL}}}$$

$$\pi_{tL} = 0{,}8769^{\frac{1{,}3}{(1{,}3-1)0{,}91}} = 0{,}535$$

16) Menghitung *Ratio Total Pressure dan Overall Pressure*:

$$\frac{P_{t9}}{P_0} = \pi_r\pi_d\pi_c\pi_b\pi_{tH}\pi_{tL}\pi_n$$

$$\frac{P_{t9}}{P_0} = 1{,}042x\ 0{,}97\ x\ 7\ x\ 0{,}96\ x\ 0{,}285x\ 0{,}535x\ 0{,}99$$

$$\frac{P_{t9}}{P_0} = 1{,}024$$

17) Menghitung rasio kecepatan aliran udara di *nozzle* dan *Sound Speed*:

$$\frac{V_9}{a_0} = \sqrt{\frac{2\tau_\lambda\tau_{tH}\tau_{tL}}{\gamma_c - 1}[1 - \left(\frac{P_{t9}}{P_9}\right)^{-(\gamma_t-1)/\gamma_t}]}$$

dimana:

$$\frac{P_{t9}}{P_9} = \left(\frac{\gamma_t + 1}{2}\right)^{\gamma_{t/(\gamma_t - 1)}}$$

Maka:

$$\frac{P_{t9}}{P_9} = \left(\frac{1{,}3+1}{2}\right)^{1{,}3/(1{,}3-1)} = 1{,}83242$$

$$\frac{P_0}{P_9} = \frac{\frac{P_{t9}}{P_9}}{\frac{P_{t9}}{P_0}} = \frac{1{,}83242}{1{,}024} = 1{,}78978$$

Sehingga:

$$\frac{V_9}{a_0} = \sqrt{\frac{2\ x\ 3{,}79084\ x\ 0{,}773\ x\ 0{,}8769}{1{,}4-1}\left[1-(1{,}83242)^{-(1{,}3-1)/1{,}3}\right]}$$

$$\frac{V_9}{a_0} = 1{,}294$$

18) Menghitung Koefisien Kerja *Output Propeller*:

$$C_{prop} = \eta_{prop}\eta_g\eta_{mL}(1+f)\tau_\lambda\tau_{tH}(1-\tau_{tL})$$

$$C_{prop} = 0{,}83x\ 0{,}99\ x\ 0{,}99x\ (1+0{,}01348)3{,}79084\ x0{,}773(1-0{,}8769)$$

$$C_{prop} = 0{,}297$$

19) Menghitung Koefisien Kerja *Compressor Core:*

$$C_c = (\gamma_c - 1)M_0\left[(1+f)\frac{V_9}{a_0} - M_0 + (1+f)\frac{R_t}{R_c}\frac{\frac{T_9}{T_0}}{\frac{V_9}{a_0}} - \frac{1-\frac{P_0}{P_9}}{\gamma_c}\right.$$

dimana:

$$\frac{T_9}{T_0} = \frac{\frac{T_{t9}}{T_0}}{\left(\frac{P_{t9}}{P_9}\right)^{(\gamma_t-1)/\gamma_t}}$$

dan

$$\frac{T_{t9}}{T_0} = \frac{T_{t4}}{T_0}\tau_{tH}\tau_{tL}$$

$$\frac{T_{t9}}{T_0} = \frac{1.715{,}67}{520{,}47}0{,}773\ x\ 0{,}8769 = 2{,}233$$

Maka:

$$\frac{T_9}{T_0} = \frac{2{,}233}{(1{,}83242)^{(1{,}3-1)/1{,}3}} = 1{,}942$$

Sehingga:

$$C_c = (1{,}4 - 1)0{,}242299\,[(1 + 0{,}01348)1{,}294 - 0{,}242299 + (1 + 0{,}01348)\frac{49{,}56281}{53{,}35954}\frac{2{,}233}{1{,}294} - \frac{1 - 1{,}78978}{1{,}4}$$

$$C_c = 0{,}0265$$

20) Menghitung koefisien kerja *output* pada *engine core total:*

$$C_{tot} = C_{prop} + C_c$$

$$C_{tot} = 0{,}297 + 0{,}0265$$

$$C_{tot} = 0{,}324$$

21) Menghitung *Thrust and Mass Flow Ratio*:

$$\frac{F}{\dot{m}_0} = \frac{C_{tot}C_{pc}T_0}{V_0}$$

$$\frac{F}{\dot{m}_0} = \frac{0{,}324\ x\ 0{,}24\ x\ 520{,}47}{271.0018}$$

$$\frac{F}{\dot{m}_0} = 195{,}958\ lbf/(lbm/sec)$$

22) Menghitung *Specific Fuel Consumption:*

$$S = \frac{f}{F/\dot{m}_0}$$

$$S = \frac{0{,}01348\ x\ 3600}{195{,}958} = 0{,}2476\ (lbm/hr)/lbf$$

23) Menghitung *Specific Power*:

$$\frac{\dot{W}}{\dot{m}_0} = C_{tot}C_{pc}T_0$$

$$\frac{\dot{W}}{\dot{m}_0} = 0{,}324x\ 0{,}24\ x\ 520{,}47$$

$$\frac{\dot{W}}{\dot{m}_0} = 40{,}438\ hp/(lbm/sec)$$

24) Menghitung *Efficiency Thermal*, *Propulsive*, *Overall*

$$\eta T = \frac{0{,}31628}{\frac{0{,}01339\ x\ 18.400}{0{,}276x524{,}07}} = 16{,}3\%$$

$$\eta P = \frac{0{,}31628}{\left(\frac{0{,}29008}{0{,}83}\right) + \left(\frac{1{,}4-1}{2}\right) x\ (1 + 0{,}01339) x\ [(1{,}2899)^2 - 0{,}239035^2]}$$

$$\eta P = 47{,}2\%$$

$$\eta O = 16{,}3\%\ x\ 47{,}2\% = 7{,}7\%$$

5. Perhitungan *performance* pada *TBO* (3.600 *hours*) pada ketinggian 8.500 *ft* berdasarkan data *aircraft flight log*. Tabel 1.6 merupakan parameter *input engine TBO* 3.600 *hours*.

Tabel 1.6 Parameter *Input Engine TBO* 3600 *hours*

Parameter	*Input*	Satuan
T_0	515,07	^{0}R
Tt_4	1.715,67	^{0}R

Perhitungan:

1) Menghitung konstanta gas di kompresor:

$$R_c = \frac{\gamma_c - 1}{\gamma_c} C_{pc}$$

$$R_c = \frac{1{,}4 - 1}{1{,}4} 0{,}24$$

$$R_c = 0{,}06857\ BTU/lbm.°R$$

$$R_c = 0{,}06857\ x\ 778{,}16\ ft.lbf/lbm.°R$$

$$R_c = 53{,}35954\ ft.lbf/lbm.°R$$

2) Menghitung konstanta gas di t*urbine*:

$$R_t = \frac{\gamma_t - 1}{\gamma_t} C_{pt}$$

$R_t = \frac{1,3-1}{1,3} 0,276 \ = 0,63692\ BTU/lbm.°R$

$R_t = 0,63692\ x\ 778,16\ \ ft.lbf/bm.°R$

$R_t = 49,56281\ \ ft.lbf/bm.°R$

3) Menghitung *Sound Speed* atau kecepatan suara:

$a_0 = \sqrt{\gamma_c\ R_c\ \ g_c\ T_0}$

$a_0 = \sqrt{1,4 \text{ x }\ 53,35954\ x\ 32,174\ x\ 515,07}$

$a_0 = 1.112,642704\ ft/sec$

4) Menghitung *Absolute velocity*:

V_0= TAS=$(\frac{FL}{1.000} x\ 2\%\ x\ 0,98\ x\ IAS) + IAS$

V_0= $(\frac{8500}{1000} x\ 2\%\ x\ 0,98\ x\ 137) + 137$

V_0= $159,824\ knot$

V_0= $159,824\ NM/hr$

V_0= $159,824\ x\ 1,852\ km/hr$

V_0= $295,994\ km/hr$

V_0= $82,221\ m/sec$

V_0= $82,221\ x\ 3,2808 = 269,72628\ ft/sec$

5) Menghitung $Ratio\ Temperature\ Ram$:

$$\tau_r = 1 + \frac{\gamma_c - 1}{2} M_0^2$$

$dimana$:

$M_0 = V_0/a_0$

$M_0 = \frac{269,72628}{1.112,642704} = 0,242419\ Mach$

$$\tau_r = 1 + \frac{1,4 - 1}{2} 0,242419\ \ ^2$$

$\tau_r = 1,012$

6) Menghitung $Ram\ Pressure\ Ratio$:

$\pi_r = \tau_r{}^{\gamma_c / (\gamma_c - 1)}$

$\pi_r = 1{,}012^{1{,}4/(1{,}4-1)} = 1{,}042$

7) Menghitung *Inlet Pressure Ratio:*

$\pi_d = \pi_{dmax}\ x\ \eta_r$

Dimana:

η_r= 1 untuk $M_0 \leq 1$

$\eta_r = 1 - 0{,}0075(M_0 - 1)^{1{,}35}$ untuk $M_0 \geq 1$

$\pi_d = 0{,}97\ x\ 1 = 0{,}97$

8) Menghitung *entalphy ratio* di ruang bakar dengan *ambient temperature* pada ketinggian terbang:

$$\tau_\lambda = \frac{C_{pt}\ x\ T_{t4}}{C_{pc} T_0}$$

$$\tau_\lambda = \frac{0{,}276\ x 1.715{,}67}{0{,}24\ x\ 515{,}07} = 3{,}83059$$

9) Menghitung *temperature ratio* di ruang bakar dengan *ambient temperature* pada ketinggian terbang :

$\tau_c = \pi_c{}^{(\gamma_c - 1)/(\gamma_c\ \varepsilon_c)}$

$\tau_c = 7^{(1{,}4-1)/(1{,}4\ x\ 0{,}90)} = 1{,}85475$

10) Menghitung *Compressor Efficiency*:

$$\eta_c = \frac{\pi_c{}^{(\gamma_c - 1)/\gamma_c} - 1}{\tau_c - 1}$$

$$\eta_c = \frac{7^{(1{,}4-1)/1{,}4} - 1}{1{,}85475 - 1} = 0{,}87$$

11) Menghitung *Fuel/Air Ratio:*

$$f = \frac{\tau_\lambda - \tau_r \tau_c}{\eta_b h_{PR}/(C_{pc} T_0) - \tau_\lambda}$$

$$f = \frac{3{,}83059 - 1{,}012\ x\ 1{,}85475}{0{,}99\ x\ 18.400/(0{,}24\ x\ 515{,}07) - 3{,}83059} = 0{,}01361$$

12) Menghitung *High Temperature Turbine*:

$$\tau_{tH} = 1 - \frac{\tau_r(\tau_c - 1)}{\eta_{mH}(1+f)\tau_\lambda}$$

$$\tau_{tH} = 1 - \frac{1{,}012\ (1{,}85475 - 1)}{0{,}99(1 + 0{,}01361)3{,}83059} = 0{,}775$$

13) Menghitung *Turbine High Temperature Ratio*:

$$\pi_{tH} = \tau_{tH}^{\gamma_t/[(\gamma_t - 1)e_{tH}]}$$

$$\pi_{tH} = 0{,}775^{\frac{1{,}3}{(1{,}3-1)0{,}89}} = 0{,}289$$

14) Menghitung *Turbine Low Temperature Ratio*:

$$\tau_{tLi}^{*} = \frac{\tau_{tH}^{-1/e_{tH}}}{\pi} + A$$

Dimana

$$\pi = (\pi_r \pi_d \pi_c \pi_b \pi_n)^{(\gamma_t - 1)/\,\gamma_t}$$

dan

$$A = \frac{\left[\frac{\gamma_c - 1}{2}\right]\left[\frac{M_0^2}{(\tau_\lambda\,\tau_{tH})}\right]}{(\eta_{prop}\eta_g\eta_{mL})^2}$$

$maka$:

$$\pi = (1{,}042\ x\ 0{,}97\ x\ 7\ x\ 0{,}96\ x\ 0{,}99)^{(1{,}3-1)/\,1{,}3} = 1{,}552$$

dan

$$A = \frac{\left[\frac{1{,}4 - 1}{2}\right]\left[\frac{0{,}242419^2}{(3{,}83059\ x\ 0{,}775)}\right]}{(0{,}83x\ 0{,}99\ x\ 0{,}99)^2} = 3{,}959\ x\ 10^{-3}$$

Selanjutnya nilai τ_{tLi}^{*} dilakukan iterasi sampai nilainya mendekati 0,0001.

$$\tau_{tLi}^{*} = \frac{0{,}775^{-1/0{,}89}}{1{,}552} + 3{,}959\ x\ 10^{-3} = 0{,}862$$

$$\tau_{tLx} = \frac{\tau_{tH}^{-1/e_{tH}}}{\pi}\tau_{tLi}^{-(1-e_{tL})/e_{tL}} + A(1+\frac{1-e_{tL}}{e_{tL}}\frac{\tau_{tH}^{-1/e_{tH}}\ \tau_{tLi}^{-1/e_{tL}}}{\pi})^2$$

$$\tau_{tLx} = \frac{0{,}775^{-1/0{,}89}}{1{,}552}0{,}862^{-(1/0{,}91)/0{,}91} +$$

$$3{,}959\ x\ 10^{-3}(1+\frac{1-0{,}91}{0{,}91}\frac{0{,}775^{-1/0{,}89}x\ 0{,}862^{-1/0{,}91}}{1{,}552})^2$$

$$\tau_{tLx} = 0{,}8753$$

$$\tau_{tLxx} = \frac{\tau_{tH}^{-1/e_{tH}}}{\pi}\tau_{tLx}^{-(1-e_{tL})/e_{tL}} + A(1+\frac{1-e_{tL}}{e_{tL}}\frac{\tau_{tH}^{-1/e_{tH}}\ \tau_{tLx}^{-1/e_{tL}}}{\pi})^2$$

$$\tau_{tLxx} = \frac{0{,}775^{-1/0{,}89}}{1{,}552}0{,}8753^{-(1/0{,}91)/0{,}91} +$$

$$3{,}959\ x\ 10^{-3}(1+\frac{1-0{,}91}{0{,}91}\frac{0{,}775^{-1/0{,}89}x\ 0{,}8753^{-1/0{,}91}}{1{,}552})^2$$

$$\tau_{tLxx} = 0{,}87397$$

$$\tau_{tLxxx} = \frac{\tau_{tH}^{-1/e_{tH}}}{\pi}\tau_{tLxx}^{-(1-e_{tL})/e_{tL}} + A(1+\frac{1-e_{tL}}{e_{tL}}\frac{\tau_{tH}^{-1/e_{tH}}\ \tau_{tLxx}^{-1/e_{tL}}}{\pi})^2$$

$$\tau_{tLxxx} = \frac{0{,}775^{-1/0{,}89}}{1{,}552}0{,}87397^{-(1/0{,}91)/0{,}91} +$$

$$3{,}959\ x\ 10^{-3}(1+\frac{1-0{,}91}{0{,}91}\frac{0{,}775^{-1/0{,}89}x\ 0{,}87397^{-1/0{,}91}}{1{,}552})^2$$

$$\tau_{tLxxx} = 0{,}8741$$

$\tau_{tLxxx} - \tau_{tLxx} = 0{,}8741 - 0{,}87397 = 0{,}00013$ telah terpenuhi iterasi. Sehingga nilai *Turbine Low Temperature Ratio* (τ_{tLi}^{*}) sebesar 0,8741

15) Menghitung *Turbine Low Pressure Ratio*:

$$\pi_{tL} = \tau_{tL}^{\frac{\gamma_t}{\gamma_t - 1 e_{tL}}}$$

$$\pi_{tL} = 0{,}8741^{\frac{1{,}3}{(1{,}3-1)0{,}91}} = 0{,}527$$

16) Menghitung *Ratio Total Pressure dan Overall Pressure*:

$$\frac{P_{t9}}{P_0} = \pi_r \pi_d \pi_c \pi_b \pi_{tH} \pi_{tL} \pi_n$$

$$\frac{P_{t9}}{P_0} = 1{,}042x\ 0{,}97\ x\ 7\ x\ 0{,}96\ x\ 0{,}289x\ 0{,}527x\ 0{,}99$$

$$\frac{P_{t9}}{P_0} = 1{,}024$$

17) Menghitung rasio kecepatan aliran udara di *nozzle* dan *Sound Speed*:

$$\frac{V_9}{a_0} = \sqrt{\frac{2\tau_\lambda \tau_{tH} \tau_{tL}}{\gamma_c - 1}[1 - \left(\frac{P_{t9}}{P_9}\right)^{-(\gamma_t - 1)/\gamma_t}]}$$

dimana:

$$\frac{P_{t9}}{P_9} = \left(\frac{\gamma_t + 1}{2}\right)^{\gamma_{t/(\gamma_t - 1)}}$$

Maka:

$$\frac{P_{t9}}{P_9} = \left(\frac{1{,}3 + 1}{2}\right)^{1{,}3/(1{,}3-1)} = 1{,}832$$

$$\frac{P_0}{P_9} = \frac{\frac{P_{t9}}{P_9}}{\frac{P_{t9}}{P_0}} = \frac{1{,}832}{1{,}024} = 1{,}789$$

Sehingga:

$$\frac{V_9}{a_0} = \sqrt{\frac{2\ x\ 3{,}83059\ x\ 0{,}775\ x\ 0{,}8741}{1{,}4 - 1}[1 - (1{,}832)^{-(1{,}3-1)/1{,}3}]}$$

$$\frac{V_9}{a_0} = 1{,}301$$

18) Menghitung Koefisien Kerja *Output Propeller*:

$$C_{prop} = \eta_{prop} \eta_g \eta_{mL} (1 + f) \tau_\lambda \tau_{tH} (1 - \tau_{tL})$$

$$C_{prop} = 0{,}83x\ 0{,}99\ x\ 0{,}99x\ (1 + 0{,}01361)3{,}83059x0{,}775(1 - 0{,}8741)$$

$$C_{prop} = 0{,}308$$

19) Menghitung Koefisien Kerja *Compressor Core:*

$$C_c = (\gamma_c - 1)M_0[(1+f)\frac{V_9}{a_0} - M_0 + (1+f)\frac{R_t}{R_c}\frac{\frac{T_9}{T_0}}{\frac{V_9}{a_0}} - \frac{1-\frac{P_0}{P_9}}{\gamma_c}$$

$dimana$:

$$\frac{T_9}{T_0} = \frac{\frac{T_{t9}}{T_0}}{\left(\frac{P_{t9}}{P_9}\right)^{(\gamma_t - 1)/\gamma_t}}$$

dan

$$\frac{T_{t9}}{T_0} = \frac{T_{t4}}{T_0}\tau_{tH}\tau_{tL}$$

$$\frac{T_{t9}}{T_0} = \frac{1.715,67}{515,07} 0,775\ x\ 0,8741 = 2,257$$

Maka:

$$\frac{T_9}{T_0} = \frac{2,257}{(1,832)^{(1,3-1)/1,3}} = 1,962$$

Sehingga:

$$C_c = (1,4-1)0,242419\ [(1+0,01361)1,301 - 0,242419 + (1+0,01361)\frac{49,56281}{53,35954}\frac{2,257}{1,301} - \frac{1-1,789}{1,4}$$

$$C_c = 0,02672$$

20) Menghitung koefisien kerja *output* pada *engine core total:*

$$C_{tot} = C_{prop} + C_c$$

$$C_{tot} = 0,308 + 0,02672$$

$$C_{tot} = 0,335$$

21) Menghitung *Thrust and Mass Flow Ratio*:

$$\frac{F}{\dot{m}_0} = \frac{C_{tot}C_{pc}T_0}{V_0}$$

$$\frac{F}{\dot{m}_0} = \frac{0,335\ x\ 0,24\ x\ 515,07}{269,72628}$$

$$\frac{F}{\dot{m}_0} = 201{,}577\ lbf/(lbm/sec)$$

22) Menghitung *Specific Fuel Consumption:*

$$S = \frac{f}{F/\dot{m}_0}$$

$$S = \frac{0{,}01361\ x\ 3600}{201{,}577} = 0{,}24314\ (lbm/hr)/lbf$$

23) Menghitung *Specific Power*:

$$\frac{\dot{W}}{\dot{m}_0} = C_{tot}C_{pc}T_0$$

$$\frac{\dot{W}}{\dot{m}_0} = 0{,}335x\ 0{,}24\ x\ 515{,}07$$

$$\frac{\dot{W}}{\dot{m}_0} = 41{,}401\ hp/(lbm/sec)$$

24) Menghitung *Efficiency Thermal*, *Propulsive*, *Overall*

$$\eta T = \frac{0{,}335}{\frac{0{,}01361\ x\ 18.400}{0{,}276x515{,}07}} = 16{,}5\%$$

$$\eta P = \frac{0{,}335}{\left(\frac{0{,}308}{0{,}83}\right) + \left(\frac{1{,}4-1}{2}\right)x\ (1 + 0{,}01361)x\ [(1{,}301)^2 - 0{,}239035^2]}$$

$$\eta P = 47{,}7\%$$

$$\eta O = 16{,}5\%\ x\ 47{,}7\% = 7{,}9\%$$

6. Perhitungan *performance* pada *TBO* (3.600 *hours*) pada ketinggian 9.500 *ft* berdasarkan data *aircraft flight log*. Tabel 1.7 merupakan parameter *input engine TBO* 3.600 *hours*.

Tabel 1.7 Parameter *Input Engine TBO* 3600 *hours*

Parameter	*Input*	Satuan
T_0	513,07	^{0}R
Tt_4	1.715,67	^{0}R

Perhitungan:

1) Menghitung konstanta gas di kompresor:

$$R_c = \frac{\gamma_c - 1}{\gamma_c} C_{pc}$$

$$R_c = \frac{1,4 - 1}{1,4} 0,24$$

$$R_c = 0,06857\ BTU/lbm.°R$$

$$R_c = 0,06857\ x\ 778,16\ ft.lbf/lbm.°R$$

$$R_c = 53,35954\ ft.lbf/lbm.°R$$

2) Menghitung konstanta gas di t*urbine*:

$$R_t = \frac{\gamma_t - 1}{\gamma_t} C_{pt}$$

$$R_t = \frac{1,3-1}{1,3} 0,276 = 0,63692\ BTU/lbm.°R$$

$$R_t = 0,63692\ x\ 778,16\ ft.lbf/bm.°R$$

$$R_t = 49,56281\ ft.lbf/bm.°R$$

3) Menghitung *Sound Speed* atau kecepatan suara:

$$a_0 = \sqrt{\gamma_c R_c\ g_c T_0}$$

$$a_0 = \sqrt{1,4 \text{ x } 53,35954\ x\ 32,174\ x\ 513,07}$$

$$a_0 = 1.110,480425\ ft/sec$$

4) Menghitung *Absolute velocity*:

V_0= TAS=$(\frac{FL}{1.000}\ x\ 2\%\ x\ 0,98\ x\ IAS) + IAS$

V_0= $(\frac{9500}{1000}\ x\ 2\%\ x\ 0,98\ x\ 135) + 135$

V_0= $160,137\ knot$

V_0= $160,137\ NM/hr$

$V_0 = 160{,}137\ x\ 1{,}852\ km/hr$

$V_0 = 296{,}574\ km/hr$

$V_0 = 82{,}382\ m/sec$

$V_0 = 82{,}382\ x\ 3{,}2808 = 270{,}25417\ ft/sec$

5) Menghitung *Ratio Temperature Ram*:

$$\tau_r = 1 + \frac{\gamma_c - 1}{2} M_0^2$$

dimana:

$M_0 = V_0/a_0$

$M_0 = \frac{270{,}25417}{1.110{,}480425} = 0{,}243367\ Mach$

$$\tau_r = 1 + \frac{1{,}4 - 1}{2} 0{,}243367^2$$

$\tau_r = 1{,}012$

6) Menghitung *Ram Pressure Ratio*:

$\pi_r = \tau_r^{\gamma_c/(\gamma_c - 1)}$

$\pi_r = 1{,}012^{1{,}4/(1{,}4-1)} = 1{,}042$

7) Menghitung *Inlet Pressure Ratio:*

$\pi_d = \pi_{dmax}\ x\ \eta_r$

Dimana:

$\eta_r = 1$ untuk $M_0 \leq 1$

$\eta_r = 1 - 0{,}0075(M_0 - 1)^{1{,}35}$ untuk $M_0 \geq 1$

$\pi_d = 0{,}97\ x\ 1 = 0{,}97$

8) Menghitung *entalphy ratio* di ruang bakar dengan *ambient temperature* pada ketinggian terbang:

$$\tau_\lambda = \frac{C_{pt}\ x\ T_{t4}}{C_{pc} T_0}$$

$$\tau_\lambda = \frac{0,276\ x 1.715,67}{0,24\ x\ 513,07} = 3,84552$$

9) Menghitung *temperature ratio* di ruang bakar dengan *ambient temperature* pada ketinggian terbang :

$$\tau_c = \pi_c^{(\gamma_c - 1)/\ (\gamma_c\ \varepsilon_c)}$$

$$\tau_c = 7^{(1,4-1)/\ (1,4\ x\ 0,90)} = 1,85475$$

10) Menghitung *Compressor Efficiency*:

$$\eta_c = \frac{\pi_c^{(\gamma_c - 1)/\gamma_c} - 1}{\tau_c - 1}$$

$$\eta_c = \frac{7^{(1,4-1)/1,4} - 1}{1,85475 - 1} = 0,87$$

11) Menghitung *Fuel/Air Ratio:*

$$f = \frac{\tau_\lambda - \tau_r \tau_c}{\eta_b h_{PR}/(C_{pc} T_0) - \tau_\lambda}$$

$$f = \frac{3,84552 - 1,012\ x\ 1,85475}{0,99\ x\ 18.400/(0,24\ x\ 513,07) - 3,84552} = 0,01366$$

12) Menghitung *High Temperature Turbine*:

$$\tau_{tH} = 1 - \frac{\tau_r(\tau_c - 1)}{\eta_{mH}(1 + f)\tau_\lambda}$$

$$\tau_{tH} = 1 - \frac{1,012\ (1,85475 - 1)}{0,99(1 + 0,01366)3,84552} = 0,776$$

13) Menghitung *Turbine High Temperature Ratio*:

$$\pi_{tH} = \tau_{tH}^{\gamma_t/[(\gamma_t - 1)e_{tH}]}$$

$$\pi_{tH} = 0,776^{\frac{1,3}{(1,3-1)0,89}} = 0,291$$

14) Menghitung *Turbine Low Temperature Ratio*:

$$\tau_{tLi}^{*} = \frac{\tau_{tH}^{-1/e_{tH}}}{\pi} + A$$

Dimana

$$\pi = (\pi_r \pi_d \pi_c \pi_b \pi_n)^{(\gamma_t - 1)/\,\gamma_t}$$

dan

$$A = \frac{\left[\frac{\gamma_c - 1}{2}\right]\left[\frac{M_0^2}{(\tau_\lambda\, \tau_{tH})}\right]}{(\eta_{prop}\eta_g\eta_{mL})^2}$$

$maka$:

$$\pi = (1{,}042\ x\ 0{,}97\ x\ 7\ x\ 0{,}96\ x\ 0{,}99)^{(1{,}3-1)/\,1{,}3} = 1{,}552$$

dan

$$A = \frac{\left[\frac{1{,}4 - 1}{2}\right]\left[\frac{0{,}243367^{\ 2}}{(3{,}84552\ x\ 0{,}776)}\right]}{(0{,}83x\ 0{,}99\ x\ 0{,}99)^2} = 3{,}97\ x\ 10^{-3}$$

Selanjutnya nilai τ_{tLi}^{*} dilakukan iterasi sampai nilainya mendekati 0,0001.

$$\tau_{tLi}^{*} = \frac{0{,}776^{-1/0{,}89}}{1{,}552} + 3{,}97\ x\ 10^{-3} = 0{,}861$$

$$\tau_{tLx} = \frac{\tau_{tH}^{-1/e_{tH}}}{\pi}\tau_{tLi}^{-(1-e_{tL})/e_{tL}} + A(1 + \frac{1 - e_{tL}}{e_{tL}}\frac{\tau_{tH}^{-1/e_{tH}}\ \tau_{tLi}^{-1/e_{tL}}}{\pi})^2$$

$$\tau_{tLx} = \frac{0{,}776^{-1/0{,}89}}{1{,}552}0{,}861^{-(1/0{,}91)/0{,}91} +$$

$$3{,}97\ x\ 10^{-3}(1 + \frac{1 - 0{,}91}{0{,}91}\frac{0{,}776^{-1/0{,}89}x\ 0{,}861^{-1/0{,}91}}{1{,}552})^2$$

$$\tau_{tLx} = 0{,}8743$$

$$\tau_{tLxx} = \frac{\tau_{tH}^{-1/e_{tH}}}{\pi}\tau_{tLx}^{-(1-e_{tL})/e_{tL}} + A(1 + \frac{1 - e_{tL}}{e_{tL}}\frac{\tau_{tH}^{-1/e_{tH}}\ \tau_{tLx}^{-1/e_{tL}}}{\pi})^2$$

$$\tau_{tLxx} = \frac{0{,}776^{-1/0{,}89}}{1{,}552}0{,}8743^{-(1/0{,}91)/0{,}91} +$$

$$3{,}97\ x\ 10^{-3}(1 + \frac{1 - 0{,}91}{0{,}91}\frac{0{,}776^{-1/0{,}89}x\ 0{,}8743^{-1/0{,}91}}{1{,}552})^2$$

$\tau_{tLxx} = 0{,}87293$

$$\tau_{tLxxx} = \frac{\tau_{tH}^{-1/e_{tH}}}{\pi}\tau_{tLxx}^{-(1-e_{tL})/e_{tL}} + A(1 + \frac{1-e_{tL}}{e_{tL}}\frac{\tau_{tH}^{-1/e_{tH}}\ \tau_{tLxx}^{-1/e_{tL}}}{\pi})^2$$

$$\tau_{tLxxx} = \frac{0{,}776^{-1/0{,}89}}{1{,}552}0{,}87293^{-(1/0{,}91)/0{,}91} +$$

$$3{,}97\ x\ 10^{-3}(1 + \frac{1-0{,}91}{0{,}91}\frac{0{,}776^{-1/0{,}89}x\ 0{,}87293^{-1/0{,}91}}{1{,}552})^2$$

$\tau_{tLxxx} = 0{,}87307$

$\tau_{tLxxx} - \tau_{tLxx} = 0{,}87307 - 0{,}87293 = 0{,}00014$ telah terpenuhi iterasi.

Sehingga nilai *Turbine Low Temperature Ratio* (τ_{tLi}^*) sebesar $0{,}87307$

15) Menghitung *Turbine Low Pressure Ratio*:

$$\pi_{tL} = \tau_{tL}^{\frac{\gamma_t}{\gamma_t - 1 e_{tL}}}$$

$$\pi_{tL} = 0{,}87307^{\frac{1{,}3}{(1{,}3-1)0{,}91}} = 0{,}524$$

16) Menghitung *Ratio Total Pressure dan Overall Pressure*:

$$\frac{P_{t9}}{P_0} = \pi_r\pi_d\pi_c\pi_b\pi_{tH}\pi_{tL}\pi_n$$

$$\frac{P_{t9}}{P_0} = 1{,}042x\ 0{,}97\ x\ 7\ x\ 0{,}96\ x\ 0{,}291x\ 0{,}524x\ 0{,}99$$

$$\frac{P_{t9}}{P_0} = 1{,}024$$

17) Menghitung rasio kecepatan aliran udara di *nozzle* dan *Sound Speed*:

$$\frac{V_9}{a_0} = \sqrt{\frac{2\tau_\lambda\tau_{tH}\tau_{tL}}{\gamma_c - 1}[1 - \left(\frac{P_{t9}}{P_9}\right)^{-(\gamma_t-1)/\gamma_t}]}$$

dimana:

$$\frac{P_{t9}}{P_9} = \left(\frac{\gamma_t + 1}{2}\right)^{\gamma_{t/(\gamma_t-1)}}$$

Maka:

$$\frac{P_{t9}}{P_9} = \left(\frac{1,3+1}{2}\right)^{1,3/(1,3-1)} = 1,832$$

$$\frac{P_0}{P_9} = \frac{\frac{P_{t9}}{P_9}}{\frac{P_{t9}}{P_0}} = \frac{1,832}{1,024} = 1,789$$

Sehingga:

$$\frac{V_9}{a_0} = \sqrt{\frac{2\ x\ 3,84552\ x\ 0,776\ x\ 0,87307}{1,4-1}\left[1-(1,832)^{-(1,3-1)/1,3}\right]}$$

$$\frac{V_9}{a_0} = 1,303$$

18) Menghitung Koefisien Kerja *Output Propeller*:

$$C_{prop} = \eta_{prop}\eta_g\eta_{mL}(1+f)\tau_\lambda\tau_{tH}(1-\tau_{tL})$$

$$C_{prop} = 0,83x\ 0,99\ x\ 0,99x\ (1+0,01366)3,84552x0,776(1-0,87307)$$

$$C_{prop} = 0,312$$

19) Menghitung Koefisien Kerja *Compressor Core:*

$$C_c = (\gamma_c - 1)M_0[(1+f)\frac{V_9}{a_0} - M_0 + (1+f)\frac{R_t}{R_c}\frac{\frac{T_9}{T_0}}{\frac{V_9}{a_0}} - \frac{1-\frac{P_0}{P_9}}{\gamma_c}$$

dimana:

$$\frac{T_9}{T_0} = \frac{\frac{T_{t9}}{T_0}}{\left(\frac{P_{t9}}{P_9}\right)^{(\gamma_t-1)/\gamma_t}}$$

dan

$$\frac{T_{t9}}{T_0} = \frac{T_{t4}}{T_0}\tau_{tH}\tau_{tL}$$

$$\frac{T_{t9}}{T_0} = \frac{1.715,67}{513,07}0,776\ x\ 0,87307 = 2,265$$

Maka:

$$\frac{T_9}{T_0} = \frac{2,265}{(1,832)^{(1,3-1)}/_{1,3}} = 1,97$$

Sehingga:

$$C_c = (1,4-1)0,243367\,[(1+0,01366)1,303 - 0,243367 + (1+0,01366)\frac{49,56281}{53,35954}\frac{2,265}{1,303} - \frac{1-1,789}{1,4}$$

$$C_c = 0,02685$$

20) Menghitung koefisien kerja *output* pada *engine core total:*

$$C_{tot} = C_{prop} + C_c$$

$$C_{tot} = 0,312 + 0,02685$$

$$C_{tot} = 0,339$$

21) Menghitung *Thrust and Mass Flow Ratio*:

$$\frac{F}{\dot{m}_0} = \frac{C_{tot}C_{pc}T_0}{V_0}$$

$$\frac{F}{\dot{m}_0} = \frac{0,339\ x\ 0,24\ x\ 513,07}{270,25417}$$

$$\frac{F}{\dot{m}_0} = 202,938\ lbf/(lbm/sec)$$

22) Menghitung *Specific Fuel Consumption:*

$$S = \frac{f}{F/_{\dot{m}_0}}$$

$$S = \frac{0,01366\ x\ 3600}{202,938} = 0,24239\ (lbm/hr)/lbf$$

23) Menghitung *Specific Power*:

$$\frac{\dot{W}}{\dot{m}_0} = C_{tot}C_{pc}T_0$$

$$\frac{\dot{W}}{\dot{m}_0} = 0,339x\ 0,24\ x\ 513,07$$

$$\frac{\dot{W}}{\dot{m}_0} = 41{,}763\ hp/(lbm/sec)$$

24) Menghitung *Efficiency Thermal*, *Propulsive*, *Overall*

$$\eta T = \frac{0{,}339}{\frac{0{,}01366\ x\ 18.400}{0{,}276x513{,}07}} = 16{,}6\%$$

$$\eta P = \frac{0{,}339}{\left(\frac{0{,}312}{0{,}83}\right) + \left(\frac{1{,}4-1}{2}\right) x\ (1 + 0{,}01366) x\ [(1{,}303)^2 - 0{,}243367^2]}$$

$$\eta P = 47{,}8\%$$

$$\eta O = 16{,}6\%\ x\ 47{,}8\% = 7{,}9\%$$

7. Perhitungan *performance* pada *TBO* (3.600 *hours*) pada ketinggian 10.500 *ft* berdasarkan data *aircraft flight log*. Tabel 1.8 merupakan parameter *input engine TBO* 3.600 *hours*.

Tabel 1.8 Parameter *Input Engine TBO* 3600 *hours*

Parameter	*Input*	Satuan
T_0	513,07	^{0}R
Tt_4	1.733,67	^{0}R

Perhitungan:

1) Menghitung konstanta gas di kompresor:

$$R_c = \frac{\gamma_c - 1}{\gamma_c} C_{pc}$$

$$R_c = \frac{1{,}4 - 1}{1{,}4} 0{,}24$$

$$R_c = 0{,}06857\ BTU/lbm.°R$$

$$R_c = 0{,}06857\ x\ 778{,}16\ ft.lbf/lbm.°R$$

$$R_c = 53{,}35954\ ft.lbf/lbm.°R$$

2) Menghitung konstanta gas di t*urbine*:

$$R_t = \frac{\gamma_t - 1}{\gamma_t} C_{pt}$$

$R_t = \frac{1,3-1}{1,3} 0,276 = 0,63692$ *BTU/lbm.°R*

$R_t = 0,63692\ x\ 778,16\ \ ft.lbf/bm.°R$

$R_t = 49,56281\ \ ft.lbf/bm.°R$

3) Menghitung *Sound Speed* atau kecepatan suara:

$a_0 = \sqrt{\gamma_c\ R_c\ \ g_c\ T_0}$

$a_0 = \sqrt{1,4\ \text{x}\ \ 53,35954\ x\ 32,174\ x\ 513,07}$

$a_0 = 1.110,480425\ ft/sec$

4) Menghitung *Absolute velocity*:

V_0= TAS=$(\frac{FL}{1.000} x\ 2\%\ x\ 0,98\ x\ IAS) + IAS$

V_0= $(\frac{10500}{1000} x\ 2\%\ x\ 0,98\ x\ 132) + 132$

V_0= $159,166\ knot$

V_0= $159,166\ NM/hr$

V_0= $159,166\ x\ 1,852\ km/hr$

V_0= $294,775\ km/hr$

V_0= $81,882\ m/sec$

V_0= $81,882\ x\ 3,2808 = 268,61479 ft/sec$

5) Menghitung $Ratio\ Temperature\ Ram$:

$$\tau_r = 1 + \frac{\gamma_c - 1}{2} M_0^2$$

$dimana$:

$M_0 = V_0/a_0$

$M_0 = \frac{268,61479}{1.110,480425} = 0,241891$ *Mach*

$$\tau_r = 1 + \frac{1,4 - 1}{2} 0,241891\ ^2$$

$$\tau_r = 1{,}012$$

6) Menghitung *Ram Pressure Ratio*:

$$\pi_r = \tau_r^{\gamma_c/\,(\gamma_c-1)}$$

$$\pi_r = 1{,}012^{1{,}4/\,(1{,}4-1)} = 1{,}042$$

7) Menghitung *Inlet Pressure Ratio:*

$$\pi_d = \pi_{dmax}\ x\ \eta_r$$

Dimana:

η_r= 1 untuk $M_0 \leq 1$

$\eta_r = 1 - 0{,}0075(M_0 - 1)^{1{,}35}$ untuk $M_0 \geq 1$

$$\pi_d = 0{,}97\ x\ 1 = 0{,}97$$

8) Menghitung *entalphy ratio* di ruang bakar dengan *ambient temperature* pada ketinggian terbang:

$$\tau_\lambda = \frac{C_{pt}\ x\ T_{t4}}{C_{pc}T_0}$$

$$\tau_\lambda = \frac{0{,}276\ x 1.733{,}67}{0{,}24\ x\ 513{,}07} = 3{,}88586$$

9) Menghitung *temperature ratio* di ruang bakar dengan *ambient temperature* pada ketinggian terbang :

$$\tau_c = \pi_c^{(\gamma_c-1)/\,(\gamma_c\ \varepsilon_c)}$$

$$\tau_c = 7^{(1{,}4-1)/\,(1{,}4\ x\ 0{,}90)} = 1{,}85475$$

10) Menghitung *Compressor Efficiency*:

$$\eta_c = \frac{\pi_c^{(\gamma_c-1)/\gamma_c} - 1}{\tau_c - 1}$$

$$\eta_c = \frac{7^{(1{,}4-1)/1{,}4} - 1}{1{,}85475 - 1} = 0{,}87$$

11) Menghitung *Fuel/Air Ratio:*

$$f = \frac{\tau_\lambda - \tau_r \tau_c}{\eta_b h_{PR}/(C_{pc} T_0) - \tau_\lambda}$$

$$f = \frac{3{,}88585 - 1{,}012\ x\ 1{,}85475}{0{,}99\ x\ 18.400/(0{,}24\ x\ 513{,}07) - 3{,}88585} = 0{,}01395$$

12) Menghitung *High Temperature Turbine*:

$$\tau_{tH} = 1 - \frac{\tau_r(\tau_c - 1)}{\eta_{mH}(1+f)\tau_\lambda}$$

$$\tau_{tH} = 1 - \frac{1{,}012\ (1{,}85475 - 1)}{0{,}99(1 + 0{,}01395)3{,}88585} = 0{,}778$$

13) Menghitung *Turbine High Temperature Ratio*:

$$\pi_{tH} = \tau_{tH}^{\gamma_t/[(\gamma_t - 1)e_{tH}]}$$

$$\pi_{tH} = 0{,}778^{\frac{1{,}3}{(1{,}3-1)0{,}89}} = 0{,}295$$

14) Menghitung *Turbine Low Temperature Ratio*:

$$\tau_{tLi}^{*} = \frac{\tau_{tH}^{-1/e_{tH}}}{\pi} + A$$

Dimana

$$\pi = (\pi_r \pi_d \pi_c \pi_b \pi_n)^{(\gamma_t - 1)/\gamma_t}$$

dan

$$A = \frac{\left[\frac{\gamma_c - 1}{2}\right]\left[\frac{M_0^2}{(\tau_\lambda\, \tau_{tH})}\right]}{(\eta_{prop}\eta_g\eta_{mL})^2}$$

$maka$:

$$\pi = (1{,}042\ x\ 0{,}97\ x\ 7\ x\ 0{,}96\ x\ 0{,}99)^{(1{,}3-1)/\,1{,}3} = 1{,}552$$

dan

$$A = \frac{\left[\frac{1{,}4 - 1}{2}\right]\left[\frac{0{,}241891^2}{(3{,}88586\ x\ 0{,}778)}\right]}{(0{,}83x\ 0{,}99\ x\ 0{,}99)^2} = 3{,}869\ x\ 10^{-3}$$

Selanjutnya nilai τ_{tLi}^{*} dilakukan iterasi sampai nilainya mendekati 0,0001.

$$\tau_{tLi}^{*} = \frac{0{,}778^{-1/0{,}89}}{1{,}552} + 3{,}869\ x\ 10^{-3} = 0{,}858$$

$$\tau_{tLx} = \frac{\tau_{tH}^{-1/e_{tH}}}{\pi}\tau_{tLi}^{-(1-e_{tL})/e_{tL}} + A(1 + \frac{1-e_{tL}}{e_{tL}}\frac{\tau_{tH}^{-1/e_{tH}}\ \tau_{tLi}^{-1/e_{tL}}}{\pi})^2$$

$$\tau_{tLx} = \frac{0{,}778^{-1/0{,}89}}{1{,}552}0{,}858^{-(1/0{,}91)/0{,}91} +$$

$$3{,}869\ x\ 10^{-3}(1 + \frac{1-0{,}91}{0{,}91}\frac{0{,}778^{-1/0{,}89}x\ 0{,}858^{-1/0{,}91}}{1{,}552})^2$$

$$\tau_{tLx} = 0{,}8715$$

$$\tau_{tLxx} = \frac{\tau_{tH}^{-1/e_{tH}}}{\pi}\tau_{tLx}^{-(1-e_{tL})/e_{tL}} + A(1 + \frac{1-e_{tL}}{e_{tL}}\frac{\tau_{tH}^{-1/e_{tH}}\ \tau_{tLx}^{-1/e_{tL}}}{\pi})^2$$

$$\tau_{tLxx} = \frac{0{,}778^{-1/0{,}89}}{1{,}552}0{,}8715^{-(1/0{,}91)/0{,}91} +$$

$$3{,}869\ x\ 10^{-3}(1 + \frac{1-0{,}91}{0{,}91}\frac{0{,}778^{-1/0{,}89}x\ 0{,}8715^{-1/0{,}91}}{1{,}552})^2$$

$$\tau_{tLxx} = 0{,}87014$$

$$\tau_{tLxxx} = \frac{\tau_{tH}^{-1/e_{tH}}}{\pi}\tau_{tLxx}^{-(1-e_{tL})/e_{tL}} + A(1 + \frac{1-e_{tL}}{e_{tL}}\frac{\tau_{tH}^{-1/e_{tH}}\ \tau_{tLxx}^{-1/e_{tL}}}{\pi})^2$$

$$\tau_{tLxxx} = \frac{0{,}778^{-1/0{,}89}}{1{,}552}0{,}87014^{-(1/0{,}91)/0{,}91} +$$

$$3{,}869\ x\ 10^{-3}(1 + \frac{1-0{,}91}{0{,}91}\frac{0{,}778^{-1/0{,}89}x\ 0{,}87014^{-1/0{,}91}}{1{,}552})^2$$

$$\tau_{tLxxx} = 0{,}87028$$

$\tau_{tLxxx} - \tau_{tLxx} = 0{,}87028 - 0{,}87014 = 0{,}00014$ telah terpenuhi iterasi.

Sehingga nilai *Turbine Low Temperature Ratio* (τ_{tLi}^{*}) sebesar 0,87028

15) Menghitung *Turbine Low Pressure Ratio*:

$$\pi_{tL} = \tau_{tL}^{\frac{\gamma_t}{\gamma_t - 1 e_{tL}}}$$

$$\pi_{tL} = 0,87028^{\frac{1,3}{(1,3-1)0,91}} = 0,518$$

16) Menghitung *Ratio Total Pressure dan Overall Pressure*:

$$\frac{P_{t9}}{P_0} = \pi_r \pi_d \pi_c \pi_b \pi_{tH} \pi_{tL} \pi_n$$

$$\frac{P_{t9}}{P_0} = 1,042x\ 0,97\ x\ 7\ x\ 0,96\ x\ 0,295x\ 0,518x\ 0,99$$

$$\frac{P_{t9}}{P_0} = 1,024$$

17) Menghitung rasio kecepatan aliran udara di *nozzle* dan *Sound Speed*:

$$\frac{V_9}{a_0} = \sqrt{\frac{2\tau_\lambda \tau_{tH} \tau_{tL}}{\gamma_c - 1}[1 - \left(\frac{P_{t9}}{P_9}\right)^{-(\gamma_t - 1)/\gamma_t}]}$$

$dimana$:

$$\frac{P_{t9}}{P_9} = \left(\frac{\gamma_t + 1}{2}\right)^{\gamma_{t/(\gamma_t - 1)}}$$

Maka:

$$\frac{P_{t9}}{P_9} = \left(\frac{1,3 + 1}{2}\right)^{1,3/(1,3-1)} = 1,832$$

$$\frac{P_0}{P_9} = \frac{\frac{P_{t9}}{P_9}}{\frac{P_{t9}}{P_0}} = \frac{1,832}{1,024} = 1,79$$

Sehingga:

$$\frac{V_9}{a_0} = \sqrt{\frac{2\ x\ 3,88586\ x\ 0,778\ x\ 0,87028}{1,4 - 1}[1 - (1,832)^{-(1,3-1)/1,3}]}$$

$$\frac{V_9}{a_0} = 1,31$$

18) Menghitung Koefisien Kerja *Output Propeller*:

$$C_{prop} = \eta_{prop} \eta_g \eta_{mL} (1 + f) \tau_\lambda \tau_{tH} (1 - \tau_{tL})$$

$$C_{prop} = 0,83x\ 0,99\ x\ 0,99x\ (1 + 0,01395)3,88586x0,778(1 - 0,87028)$$

$$C_{prop} = 0,324$$

19) Menghitung Koefisien Kerja *Compressor Core:*

$$C_c = (\gamma_c - 1)M_0[(1+f)\frac{V_9}{a_0} - M_0 + (1+f)\frac{R_t}{R_c}\frac{\frac{T_9}{T_0}}{\frac{V_9}{a_0}} - \frac{1-\frac{P_0}{P_9}}{\gamma_c}$$

$dimana$:

$$\frac{T_9}{T_0} = \frac{\frac{T_{t9}}{T_0}}{\left(\frac{P_{t9}}{P_9}\right)^{(\gamma_t - 1)/\gamma_t}}$$

dan

$$\frac{T_{t9}}{T_0} = \frac{T_{t4}}{T_0}\tau_{tH}\tau_{tL}$$

$$\frac{T_{t9}}{T_0} = \frac{1.733,67}{513,07}0,778\ x\ 0,87028 = 2,289$$

Maka:

$$\frac{T_9}{T_0} = \frac{2,289}{(1,832)^{(1,3-1)/1,3}} = 1,99$$

Sehingga:

$$C_c = (1,4-1)0,241891\ [(1+0,01395)1,31 - 0,241891 + (1+0,01395)\frac{49,56281}{53,35954}\frac{2,289}{1,31} - \frac{1-1,79}{1,4}$$

$$C_c = 0,02701$$

20) Menghitung koefisien kerja *output* pada *engine core total:*

$$C_{tot} = C_{prop} + C_c$$

$$C_{tot} = 0,324 + 0,02701$$

$$C_{tot} = 0,351$$

21) Menghitung *Thrust and Mass Flow Ratio*:

$$\frac{F}{\dot{m}_0} = \frac{C_{tot}C_{pc}T_0}{V_0}$$

$$\frac{F}{\dot{m}_0} = \frac{0,351\ x\ 0,24\ x\ 513,07}{268,61479}$$

$$\frac{F}{\dot{m}_0} = 211,072\ lbf/(lbm/sec)$$

22) Menghitung *Specific Fuel Consumption:*

$$S = \frac{f}{F/_{\dot{m}_0}}$$

$$S = \frac{0,01395\ x\ 3600}{211,072} = 0,23792\ (lbm/hr)/lbf$$

23) Menghitung *Specific Power*:

$$\frac{\dot{W}}{\dot{m}_0} = C_{tot}C_{pc}T_0$$

$$\frac{\dot{W}}{\dot{m}_0} = 0,351x\ 0,24\ x\ 513,07$$

$$\frac{\dot{W}}{\dot{m}_0} = 43,173\ hp/(lbm/sec)$$

24) Menghitung *Efficiency Thermal*, *Propulsive*, *Overall*

$$\eta T = \frac{0,351}{\frac{0,01395\ x\ 18.400}{0,276x513,07}} = 16,8\%$$

$$\eta P = \frac{0,351}{\left(\frac{0,324}{0,83}\right) + \left(\frac{1,4-1}{2}\right) x\ (1 + 0,01395) x\ [(1,31)^2 - 0,241891^2]}$$

$$\eta P = 48,3\%$$

$$\eta O = 16,6\%\ x\ 47,8\% = 8,1\%$$

8. Perhitungan *performance* pada *TBO* (3.600 *hours*) pada ketinggian 11.500 *ft* berdasarkan data *aircraft flight log*. Tabel 1.9 merupakan parameter *input engine TBO* 3.600 *hours*.

Tabel 1.9 Parameter *Input Engine TBO* 3600 *hours*

Parameter	*Input*	Satuan
T_0	507,87	^0R
Tt_4	1.733,67	^0R

Perhitungan:

1) Menghitung konstanta gas di kompresor:

$$R_c = \frac{\gamma_c - 1}{\gamma_c} C_{pc}$$

$$R_c = \frac{1,4 - 1}{1,4} 0,24$$

$$R_c = 0,06857\ BTU/lbm.°R$$

$$R_c = 0,06857\ x\ 778,16\ ft.lbf/lbm.°R$$

$$R_c = 53,35954\ ft.lbf/lbm.°R$$

2) Menghitung konstanta gas di t*urbine*:

$$R_t = \frac{\gamma_t - 1}{\gamma_t} C_{pt}$$

$$R_t = \frac{1,3-1}{1,3} 0,276 = 0,63692\ BTU/lbm.°R$$

$$R_t = 0,63692\ x\ 778,16\ ft.lbf/bm.°R$$

$$R_t = 49,56281\ ft.lbf/bm.°R$$

3) Menghitung *Sound Speed* atau kecepatan suara:

$$a_0 = \sqrt{\gamma_c\ R_c\ g_c\ T_0}$$

$$a_0 = \sqrt{1,4\ \text{x}\ 53,35954\ x\ 32,174\ x\ 507,87}$$

$$a_0 = 1.104,838696\ ft/sec$$

4) Menghitung *Absolute velocity*:

V_0= TAS=$(\frac{FL}{1.000}x\ 2\%\ x\ 0{,}98\ x\ IAS)+IAS$

V_0= $(\frac{11500}{1000}x\ 2\%\ x\ 0{,}98\ x\ 125)+125$

V_0= $153{,}175\ knot$

V_0= $153{,}175\ NM/hr$

V_0= $153{,}175\ x\ 1{,}852\ km/hr$

V_0= $283{,}68\ km/hr$

V_0= $78{,}8\ m/sec$

V_0=$78{,}8\ x\ 3{,}2808 = 258{,}5048\ ft/sec$

5) Menghitung $Ratio\ Temperature\ Ram$:

$$\tau_r = 1 + \frac{\gamma_c - 1}{2} M_0^2$$

$dimana$:

$M_0 = V_0/a_0$

$M_0 = \frac{258{,}5048}{1.104{,}838696} = 0{,}233975\ Mach$

$$\tau_r = 1 + \frac{1{,}4 - 1}{2} 0{,}233975^2$$

$\tau_r = 1{,}012$

6) Menghitung $Ram\ Pressure\ Ratio$:

$\pi_r = \tau_r{}^{\gamma_c/\ (\gamma_c - 1)}$

$\pi_r = 1{,}012^{1{,}4/\ (1{,}4-1)} = 1{,}042$

7) Menghitung *Inlet Pressure Ratio:*

$\pi_d = \pi_{dmax}\ x\ \eta_r$

Dimana:

η_r= 1 untuk $M_0 \leq 1$

$\eta_r = 1 - 0{,}0075(M_0 - 1)^{1{,}35}$ untuk $M_0 \geq 1$

$\pi_d = 0{,}97\ x\ 1 = 0{,}97$

8) Menghitung *entalphy ratio* di ruang bakar dengan *ambient temperature* pada ketinggian terbang:

$$\tau_\lambda = \frac{C_{pt}\ x\ T_{t4}}{C_{pc}T_0}$$

$$\tau_\lambda = \frac{0{,}276\ x 1.733{,}67}{0{,}24\ x\ 507{,}87} = 3{,}92565$$

9) Menghitung *temperature ratio* di ruang bakar dengan *ambient temperature* pada ketinggian terbang :

$$\tau_c = \pi_c{}^{(\gamma_c - 1)/\ (\gamma_c\ \varepsilon_c)}$$

$$\tau_c = 7^{(1{,}4-1)/\ (1{,}4\ x\ 0{,}90)} = 1{,}85475$$

10) Menghitung *Compressor Efficiency*:

$$\eta_c = \frac{\pi_c{}^{(\gamma_c-1)/\gamma_c} - 1}{\tau_c - 1}$$

$$\eta_c = \frac{7^{(1{,}4-1)/1{,}4} - 1}{1{,}85475 - 1} = 0{,}87$$

11) Menghitung *Fuel/Air Ratio:*

$$f = \frac{\tau_\lambda - \tau_r\tau_c}{\eta_b h_{PR}/(C_{pc}T_0) - \tau_\lambda}$$

$$f = \frac{3{,}92565 - 1{,}012\ x\ 1{,}85475}{0{,}99\ x\ 18.400/(0{,}24\ x\ 507{,}87) - 3{,}92565} = 0{,}01409$$

12) Menghitung *High Temperature Turbine*:

$$\tau_{tH} = 1 - \frac{\tau_r(\tau_c - 1)}{\eta_{mH}(1+f)\tau_\lambda}$$

$$\tau_{tH} = 1 - \frac{1{,}012\ (1{,}85475 - 1)}{0{,}99(1 + 0{,}01409)3{,}92565} = 0{,}781$$

13) Menghitung *Turbine High Temperature Ratio*:

$$\pi_{tH} = \tau_{tH}^{\gamma_t/[(\gamma_t-1)e_{tH}]}$$

$$\pi_{tH} = 0{,}781^{\frac{1{,}3}{(1{,}3-1)0{,}89}} = 0{,}3$$

14) Menghitung *Turbine Low Temperature Ratio*:

$$\tau_{tLi}^{*} = \frac{\tau_{tH}^{-1/e_{tH}}}{\pi} + A$$

Dimana

$$\pi = (\pi_r \pi_d \pi_c \pi_b \pi_n)^{(\gamma_t - 1)/\, \gamma_t}$$

dan

$$A = \frac{\left[\frac{\gamma_c - 1}{2}\right]\left[\frac{M_0^2}{(\tau_\lambda\, \tau_{tH})}\right]}{(\eta_{prop}\eta_g\eta_{mL})^2}$$

$maka$:

$$\pi = (1{,}042\ x\ 0{,}97\ x\ 7\ x\ 0{,}96\ x\ 0{,}99)^{(1{,}3-1)/\,1{,}3} = 1{,}552$$

dan

$$A = \frac{\left[\frac{1{,}4 - 1}{2}\right]\left[\frac{0{,}233975^2}{(3{,}92565\ x\ 0{,}781)}\right]}{(0{,}83x\ 0{,}99\ x\ 0{,}99)^2} = 3{,}572\ x\ 10^{-3}$$

Selanjutnya nilai τ_{tLi}^{*} dilakukan iterasi sampai nilainya mendekati 0,0001.

$$\tau_{tLi}^{*} = \frac{0{,}781^{-1/0{,}89}}{1{,}552} + 3{,}572\ x\ 10^{-3} = 0{,}855$$

$$\tau_{tLx} = \frac{\tau_{tH}^{-1/e_{tH}}}{\pi}\tau_{tLi}^{-(1-e_{tL})/e_{tL}} + A(1 + \frac{1 - e_{tL}}{e_{tL}}\frac{\tau_{tH}^{-1/e_{tH}}\ \tau_{tLi}^{-1/e_{tL}}}{\pi})^2$$

$$\tau_{tLx} = \frac{0{,}781^{-1/0{,}89}}{1{,}552}0{,}855^{-(1/0{,}91)/0{,}91} +$$

$$3{,}572\ x\ 10^{-3}(1 + \frac{1 - 0{,}91}{0{,}91}\frac{0{,}0{,}781^{-1/0{,}89}x\ 0{,}855^{-1/0{,}91}}{1{,}552})^2$$

$$\tau_{tLx} = 0{,}8689$$

$$\tau_{tLxx} = \frac{\tau_{tH}^{-1/e_{tH}}}{\pi}\tau_{tLx}^{-(1-e_{tL})/e_{tL}} + A(1 + \frac{1 - e_{tL}}{e_{tL}}\frac{\tau_{tH}^{-1/e_{tH}}\ \tau_{tLx}^{-1/e_{tL}}}{\pi})^2$$

$$\tau_{tLxx} = \frac{0{,}781^{-1/0{,}89}}{1{,}552}0{,}8689^{-(1/0{,}91)/0{,}91} +$$

$$3{,}572\ x\ 10^{-3}(1+\frac{1-0{,}91}{0{,}91}\frac{0{,}0{,}781^{-1/0{,}89}x\ 0{,}8689^{-1/0{,}91}}{1{,}552})^2$$

$$\tau_{tLxx} = 0{,}86752$$

$$\tau_{tLxxx} = \frac{\tau_{tH}^{-1/e_{tH}}}{\pi}\tau_{tLxx}^{-(1-e_{tL})/e_{tL}} + A(1+\frac{1-e_{tL}}{e_{tL}}\frac{\tau_{tH}^{-1/e_{tH}}\ \tau_{tLxx}^{-1/e_{tL}}}{\pi})^2$$

$$\tau_{tLxxx} = \frac{0{,}781^{-1/0{,}89}}{1{,}552}0{,}86752^{-(1/0{,}91)/0{,}91} +$$

$$3{,}572\ x\ 10^{-3}(1+\frac{1-0{,}91}{0{,}91}\frac{0{,}781^{-1/0{,}89}x\ 0{,}867524^{-1/0{,}91}}{1{,}552})^2$$

$$\tau_{tLxxx} = 0{,}86766$$

$\tau_{tLxxx} - \tau_{tLxx} = 0{,}86766 - 0{,}86752 = 0{,}00014$ telah terpenuhi iterasi.

Sehingga nilai *Turbine Low Temperature Ratio* (τ_{tLi}^*) sebesar 0,86766

15) Menghitung *Turbine Low Pressure Ratio*:

$$\pi_{tL} = \tau_{tL}^{\frac{\gamma_t}{\gamma_t - 1 e_{tL}}}$$

$$\pi_{tL} = 0{,}86766^{\frac{1{,}3}{(1{,}3-1)0{,}91}} = 0{,}509$$

16) Menghitung *Ratio Total Pressure dan Overall Pressure*:

$$\frac{P_{t9}}{P_0} = \pi_r\pi_d\pi_c\pi_b\pi_{tH}\pi_{tL}\pi_n$$

$$\frac{P_{t9}}{P_0} = 1{,}042x\ 0{,}97\ x\ 7\ x\ 0{,}96\ x\ 0{,}3x\ 0{,}509x\ 0{,}99$$

$$\frac{P_{t9}}{P_0} = 1{,}022$$

17) Menghitung rasio kecepatan aliran udara di *nozzle* dan *Sound Speed*:

$$\frac{V_9}{a_0} = \sqrt{\frac{2\tau_\lambda\tau_{tH}\tau_{tL}}{\gamma_c - 1}[1-\left(\frac{P_{t9}}{P_9}\right)^{-(\gamma_t-1)/\gamma_t}]}$$

$dimana$:

$$\frac{P_{t9}}{P_9} = \left(\frac{\gamma_t + 1}{2}\right)^{\gamma_{t/(\gamma_t - 1)}}$$

Maka:

$$\frac{P_{t9}}{P_9} = \left(\frac{1{,}3 + 1}{2}\right)^{1{,}3_{/(1{,}3-1)}} = 1{,}832$$

$$\frac{P_0}{P_9} = \frac{\frac{P_{t9}}{P_9}}{\frac{P_{t9}}{P_0}} = \frac{1{,}832}{1{,}022} = 1{,}793$$

Sehingga:

$$\frac{V_9}{a_0} = \sqrt{\frac{2\ x\ 3{,}92565\ x\ 0{,}781\ x\ 0{,}86766}{1{,}4 - 1}\left[1 - (1{,}832)^{-(1{,}3-1)/1{,}3}\right]}$$

$$\frac{V_9}{a_0} = 1{,}317$$

18) Menghitung Koefisien Kerja *Output Propeller*:

$$C_{prop} = \eta_{prop}\eta_g\eta_{mL}(1 + f)\tau_\lambda\tau_{tH}(1 - \tau_{tL})$$

$$C_{prop} = 0{,}83x\ 0{,}99\ x\ 0{,}99x\ (1 + 0{,}01409)3{,}92565x0{,}781(1 - 0{,}86766)$$

$$C_{prop} = 0{,}335$$

19) Menghitung Koefisien Kerja *Compressor Core:*

$$C_c = (\gamma_c - 1)M_0[(1 + f)\frac{V_9}{a_0} - M_0 + (1 + f)\frac{R_t}{R_c}\frac{\frac{T_9}{T_0}}{\frac{V_9}{a_0}} - \frac{1 - \frac{P_0}{P_9}}{\gamma_c}$$

dimana:

$$\frac{T_9}{T_0} = \frac{\frac{T_{t9}}{T_0}}{\left(\frac{P_{t9}}{P_9}\right)^{(\gamma_t - 1)/\gamma_t}}$$

dan

$$\frac{T_{t9}}{T_0} = \frac{T_{t4}}{T_0}\tau_{tH}\tau_{tL}$$

$$\frac{T_{t9}}{T_0} = \frac{1.733,67}{507,87} 0,781x\ 0,86766 = 2,312$$

Maka:

$$\frac{T_9}{T_0} = \frac{2,289}{(1,832)^{(1,3-1)}/_{1,3}} = 2,011$$

Sehingga:

$$C_c = (1,4-1)0,233975\ [(1+0,01409)1,317 - 0,233975 + (1+0,01409)\frac{49,56281}{53,35954}\frac{2,312}{1,317} - \frac{1-1,793}{1,4}$$

$$C_c = 0,02683$$

20) Menghitung koefisien kerja *output* pada *engine core total:*

$$C_{tot} = C_{prop} + C_c$$

$$C_{tot} = 0,335 + 0,02683$$

$$C_{tot} = 0,361$$

21) Menghitung *Thrust and Mass Flow Ratio*:

$$\frac{F}{\dot{m}_0} = \frac{C_{tot} C_{pc} T_0}{V_0}$$

$$\frac{F}{\dot{m}_0} = \frac{0,361\ x\ 0,24\ x\ 507,87}{258,5048}$$

$$\frac{F}{\dot{m}_0} = 223,81\ lbf/(lbm/sec)$$

22) Menghitung *Specific Fuel Consumption:*

$$S = \frac{f}{F/_{\dot{m}_0}}$$

$$S = \frac{0,01409\ x\ 3600}{223,81} = 0,22666\ (lbm/hr)/lbf$$

23) Menghitung *Specific Power*:

$$\frac{\dot{W}}{\dot{m}_0} = C_{tot} C_{pc} T_0$$

$$\frac{\dot{W}}{\dot{m}_0} = 0{,}361 x\ 0{,}24\ x\ 507{,}87$$

$$\frac{\dot{W}}{\dot{m}_0} = 44{,}055\ hp/(lbm/sec)$$

24) Menghitung *Efficiency Thermal*, *Propulsive*, *Overall*

$$\eta T = \frac{0{,}361}{\frac{0{,}01409\ x\ 18.400}{0{,}276 x 507{,}87}} = 17\%$$

$$\eta P = \frac{0{,}361}{\left(\frac{0{,}335}{0{,}83}\right) + \left(\frac{1{,}4 - 1}{2}\right) x\ (1 + 0{,}01409) x\ [(1{,}317)^2 - 0{,}233975^2]}$$

$$\eta P = 48{,}6\%$$

$$\eta O = 17\%\ x\ 48{,}6\% = 8{,}3\%$$

9. Perhitungan *performance* pada *TBO* (3.600 *hours*) pada ketinggian 12.500 *ft* berdasarkan data *aircraft flight log*. Tabel 1.10 merupakan parameter *input engine TBO* 3.600 *hours*.

Tabel 1.10 Parameter *Input Engine TBO* 3600 *hours*

Parameter	*Input*	Satuan
T_0	497,07	^{0}R
Tt_4	1.751,67	^{0}R

Perhitungan:

1) Menghitung konstanta gas di kompresor:

$$R_c = \frac{\gamma_c - 1}{\gamma_c} C_{pc}$$

$$R_c = \frac{1{,}4 - 1}{1{,}4} 0{,}24$$

$R_c = 0{,}06857\ BTU/lbm.°R$

$R_c = 0{,}06857\ x\ 778{,}16\ ft.lbf/lbm.°R$

$R_c = 53{,}35954\ ft.lbf/lbm.°R$

2) Menghitung konstanta gas di t*urbine*:

$$R_t = \frac{\gamma_t - 1}{\gamma_t} C_{pt}$$

$R_t = \frac{1{,}3-1}{1{,}3} 0{,}276 = 0{,}63692$ *BTU/lbm.°R*

$R_t = 0{,}63692\ x\ 778{,}16\ \ ft.lbf/bm.°R$

$R_t = 49{,}56281\ \ ft.lbf/bm.°R$

3) Menghitung *Sound Speed* atau kecepatan suara:

$a_0 = \sqrt{\gamma_c\ R_c\ \ g_c\ T_0}$

$a_0 = \sqrt{1{,}4 \text{ x } 53{,}35954\ x\ 32{,}174\ x\ 497{,}07}$

$a_0 = 1.093{,}028216\ ft/sec$

4) Menghitung *Absolute velocity*:

V_0= TAS=$(\frac{FL}{1.000} x\ 2\%\ x\ 0{,}98\ x\ IAS) + IAS$

V_0= $(\frac{12500}{1000} x\ 2\%\ x\ 0{,}98\ x\ 125) + 125$

V_0= $155{,}625\ knot$

V_0= $155{,}625\ NM/hr$

V_0= $155{,}625\ x\ 1{,}852\ km/hr$

V_0= $288{,}218\ km/hr$

V_0= $80{,}06 m/sec$

V_0= $80{,}06 x\ 3{,}2808 = 262{,}63952\ ft/sec$

5) Menghitung $Ratio\ Temperature\ Ram$:

$$\tau_r = 1 + \frac{\gamma_c - 1}{2} M_0^2$$

$dimana$:

$M_0 = V_0/a_0$

$M_0 = \frac{262,63952}{1.093,028216} = 0,240286\ Mach$

$\tau_r = 1 + \frac{1,4-1}{2} 0,240286\ ^2$

$\tau_r = 1,012$

6) Menghitung $Ram\ Pressure\ Ratio$:

$\pi_r = \tau_r{}^{\gamma_c/\ (\gamma_c - 1)}$

$\pi_r = 1,012^{1,4/\ (1,4-1)} = 1,041$

7) Menghitung *Inlet Pressure Ratio:*

$\pi_d = \pi_{dmax}\ x\ \eta_r$

Dimana:

η_r= 1 untuk $M_0 \leq 1$

$\eta_r = 1 - 0,0075(M_0 - 1)^{1,35}$ untuk $M_0 \geq 1$

$\pi_d = 0,97\ x\ 1 = 0,97$

8) Menghitung *entalphy ratio* di ruang bakar dengan *ambient temperature* pada ketinggian terbang:

$\tau_\lambda = \frac{C_{pt}\ x\ T_{t4}}{C_{pc} T_0}$

$\tau_\lambda = \frac{0,276\ x 1.751,67}{0,24\ x\ 497,07} = 4,05259$

9) Menghitung *temperature ratio* di ruang bakar dengan *ambient temperature* pada ketinggian terbang :

$\tau_c = \pi_c{}^{(\gamma_c - 1)/\ (\gamma_c\ \varepsilon_c)}$

$\tau_c = 7^{(1,4-1)/\ (1,4\ x\ 0,90)} = 1,85475$

10) Menghitung *Compressor Efficiency*:

$$\eta_c = \frac{\pi_c{}^{(\gamma_c-1)/\gamma_c} - 1}{\tau_c - 1}$$

$$\eta_c = \frac{7^{(1,4-1)/1,4} - 1}{1,85475 - 1} = 0,87$$

11) Menghitung *Fuel/Air Ratio:*

$$f = \frac{\tau_\lambda - \tau_r \tau_c}{\eta_b h_{PR}/(C_{pc} T_0) - \tau_\lambda}$$

$$f = \frac{4,05259 - 1,012\ x\ 1,85475}{0,99\ x\ 18.400/(0,24\ x\ 497,07) - 4,05259} = 0,014642$$

12) Menghitung *High Temperature Turbine*:

$$\tau_{tH} = 1 - \frac{\tau_r(\tau_c - 1)}{\eta_{mH}(1 + f)\tau_\lambda}$$

$$\tau_{tH} = 1 - \frac{1,012\ (1,85475 - 1)}{0,99(1 + 0,014642)4,05259} = 0,788$$

13) Menghitung *Turbine High Temperature Ratio*:

$$\pi_{tH} = \tau_{tH}^{\gamma_t/[(\gamma_t-1)e_{tH}]}$$

$$\pi_{tH} = 0,788^{\frac{1,3}{(1,3-1)0,89}} = 0,313$$

14) Menghitung *Turbine Low Temperature Ratio*:

$$\tau_{tLi}^* = \frac{\tau_{tH}^{-1/e_{tH}}}{\pi} + A$$

Dimana

$$\pi = (\pi_r \pi_d \pi_c \pi_b \pi_n)^{(\gamma_t-1)/\gamma_t}$$

dan

$$A = \frac{\left[\frac{\gamma_c - 1}{2}\right]\left[\frac{M_0^2}{(\tau_\lambda\, \tau_{tH})}\right]}{(\eta_{prop}\eta_g\eta_{mL})^2}$$

$maka$:

$$\pi = (1,042\ x\ 0,97\ x\ 7\ x\ 0,96\ x\ 0,99)^{(1,3-1)/\ 1,3} = 1,552$$

dan

$$A = \frac{\left[\frac{1,4-1}{2}\right]\left[\frac{0,240286^2}{(4,05259\ x\ 0,788)}\right]}{(0,83x\ 0,99\ x\ 0,99)^2} = 3,618\ x\ 10^{-3}$$

Selanjutnya nilai τ_{tLi}^* dilakukan iterasi sampai nilainya mendekati 0,0001.

$$\tau_{tLi}^* = \frac{0,788^{-1/0,89}}{1,552} + 3,618\ x\ 10^{-3} = 0,846$$

$$\tau_{tLx} = \frac{\tau_{tH}^{-1/e_{tH}}}{\pi}\tau_{tLi}^{-(1-e_{tL})/e_{tL}} + A(1 + \frac{1-e_{tL}}{e_{tL}}\frac{\tau_{tH}^{-1/e_{tH}}\ \tau_{tLi}^{-1/e_{tL}}}{\pi})^2$$

$$\tau_{tLx} = \frac{0,788^{-1/0,89}}{1,552}0,846^{-(1/0,91)/0,91} +$$

$$3,618\ x\ 10^{-3}(1 + \frac{1-0,91}{0,91}\frac{0,788^{-1/0,89}x\ 0,846^{-1/0,91}}{1,552})^2$$

$$\tau_{tLx} = 0,861$$

$$\tau_{tLxx} = \frac{\tau_{tH}^{-1/e_{tH}}}{\pi}\tau_{tLx}^{-(1-e_{tL})/e_{tL}} + A(1 + \frac{1-e_{tL}}{e_{tL}}\frac{\tau_{tH}^{-1/e_{tH}}\ \tau_{tLx}^{-1/e_{tL}}}{\pi})^2$$

$$\tau_{tLxx} = \frac{0,788^{-1/0,89}}{1,552}0,861^{-(1/0,91)/0,91} +$$

$$3,618\ x\ 10^{-3}(1 + \frac{1-0,91}{0,91}\frac{0,788^{-1/0,89}x\ 0,861^{-1/0,91}}{1,552})^2$$

$$\tau_{tLxx} = 0,8595$$

$$\tau_{tLxxx} = \frac{\tau_{tH}^{-1/e_{tH}}}{\pi}\tau_{tLxx}^{-(1-e_{tL})/e_{tL}} + A(1 + \frac{1-e_{tL}}{e_{tL}}\frac{\tau_{tH}^{-1/e_{tH}}\ \tau_{tLxx}^{-1/e_{tL}}}{\pi})^2$$

$$\tau_{tLxxx} = \frac{0,788^{-1/0,89}}{1,552}0,8595^{-(1/0,91)/0,91} +$$

$$3,618\ x\ 10^{-3}(1 + \frac{1-0,91}{0,91}\frac{0,788^{-1/0,89}x\ 0,8595^{-1/0,91}}{1,552})^2$$

$$\tau_{tLxxx} = 0,85965$$

$\tau_{tLxxx} - \tau_{tLxx} = 0,85965 - 0,8595 = 0,00015$ telah terpenuhi iterasi.

Sehingga nilai *Turbine Low Temperature Ratio* (τ_{tLi}^*) sebesar 0,85965

15) Menghitung *Turbine Low Pressure Ratio*:

$$\pi_{tL} = \tau_{tL}^{\gamma \frac{t}{\gamma_t - 1 e_{tL}}}$$

$$\pi_{tL} = 0{,}85965^{\frac{1{,}3}{(1{,}3-1)0{,}91}} = 0{,}487$$

16) Menghitung *Ratio Total Pressure dan Overall Pressure*:

$$\frac{P_{t9}}{P_0} = \pi_r \pi_d \pi_c \pi_b \pi_{tH} \pi_{tL} \pi_n$$

$$\frac{P_{t9}}{P_0} = 1{,}041 x\ 0{,}97\ x\ 7\ x\ 0{,}96\ x\ 0{,}313\ x\ 0{,}487 x\ 0{,}99$$

$$\frac{P_{t9}}{P_0} = 1{,}022$$

17) Menghitung rasio kecepatan aliran udara di *nozzle* dan *Sound Speed*:

$$\frac{V_9}{a_0} = \sqrt{\frac{2\tau_\lambda \tau_{tH} \tau_{tL}}{\gamma_c - 1} [1 - \left(\frac{P_{t9}}{P_9}\right)^{-(\gamma_t - 1)/\gamma_t}]}$$

$dimana$:

$$\frac{P_{t9}}{P_9} = \left(\frac{\gamma_t + 1}{2}\right)^{\gamma_{t/(\gamma_t - 1)}}$$

Maka:

$$\frac{P_{t9}}{P_9} = \left(\frac{1{,}3 + 1}{2}\right)^{1{,}3/(1{,}3-1)} = 1{,}832$$

$$\frac{P_0}{P_9} = \frac{\frac{P_{t9}}{P_9}}{\frac{P_{t9}}{P_0}} = \frac{1{,}832}{1{,}022} = 1{,}792$$

Sehingga:

$$\frac{V_9}{a_0} = \sqrt{\frac{2\ x\ 4{,}05259\ x\ 0{,}788\ x\ 0{,}85965}{1{,}4 - 1} [1 - (1{,}832)^{-(1{,}3-1)/1{,}3}]}$$

$$\frac{V_9}{a_0} = 1{,}338$$

18) Menghitung Koefisien Kerja *Output Propeller*:

$$C_{prop} = \eta_{prop}\eta_g\eta_{mL}(1+f)\tau_\lambda\tau_{tH}(1-\tau_{tL})$$

$$C_{prop} = 0{,}83x\ 0{,}99\ x\ 0{,}99x(1+0{,}014642)\ 4{,}05259\ x\ 0{,}788\ (1-0{,}85965)$$

$$C_{prop} = 0{,}37$$

19) Menghitung Koefisien Kerja *Compressor Core:*

$$C_c = (\gamma_c - 1)M_0[(1+f)\frac{V_9}{a_0} - M_0 + (1+f)\frac{R_t}{R_c}\frac{\frac{T_9}{T_0}}{\frac{V_9}{a_0}} - \frac{1-\frac{P_0}{P_9}}{\gamma_c}$$

$dimana$:

$$\frac{T_9}{T_0} = \frac{\frac{T_{t9}}{T_0}}{\left(\frac{P_{t9}}{P_9}\right)^{(\gamma_t-1)/\gamma_t}}$$

dan

$$\frac{T_{t9}}{T_0} = \frac{T_{t4}}{T_0}\tau_{tH}\tau_{tL}$$

$$\frac{T_{t9}}{T_0} = \frac{1.751{,}67}{497{,}07}0{,}788x\ 0{,}85965 = 2{,}386$$

Maka:

$$\frac{T_9}{T_0} = \frac{2{,}386}{(1{,}832)^{(1{,}3-1)/1{,}3}} = 2{,}075$$

Sehingga:

$$C_c = (1{,}4-1)0{,}240286\ [(1+0{,}014642)1{,}338 - 0{,}240286 + (1+0{,}014642)\frac{49{,}56281}{53{,}35954}\frac{2{,}386}{1{,}338} - \frac{1-1{,}792}{1{,}4}$$

$$C_c = 0{,}02785$$

20) Menghitung koefisien kerja *output* pada *engine core total:*

$$C_{tot} = C_{prop} + C_c$$

$$C_{tot} = 0{,}37 + 0{,}02785$$

$C_{tot} = 0{,}398$

21) Menghitung *Thrust and Mass Flow Ratio*:

$$\frac{F}{\dot{m}_0} = \frac{C_{tot} C_{pc} T_0}{V_0}$$

$$\frac{F}{\dot{m}_0} = \frac{0{,}398\ x\ 0{,}24\ x\ 497{,}07}{262{,}63952}$$

$$\frac{F}{\dot{m}_0} = 237{,}176\ lbf/(lbm/sec)$$

22) Menghitung *Specific Fuel Consumption:*

$$S = \frac{f}{F/\dot{m}_0}$$

$$S = \frac{0{,}014642\ x\ 3600}{237{,}176} = 0{,}22225 (lbm/hr)/lbf$$

23) Menghitung *Specific Power*:

$$\frac{\dot{W}}{\dot{m}_0} = C_{tot} C_{pc} T_0$$

$$\frac{\dot{W}}{\dot{m}_0} = 0{,}398 x\ 0{,}24\ x\ 497{,}07$$

$$\frac{\dot{W}}{\dot{m}_0} = 47{,}433\ hp/(lbm/sec)$$

24) Menghitung *Efficiency Thermal*, *Propulsive*, *Overall*

$$\eta T = \frac{0{,}398}{\frac{0{,}014642 x\ 18.400}{0{,}276 x 497{,}07}} = 17{,}6\%$$

$$\eta P = \frac{0{,}398}{\left(\frac{0{,}37}{0{,}83}\right) + \left(\frac{1{,}4 - 1}{2}\right) x\ (1 + 0{,}014642) x\ [(1{,}338)^2 - 0{,}240286^2]}$$

$$\eta P = 49{,}9\%$$

$\eta O = 17{,}6\% \; x \; 49{,}9\% = 8{,}8\%$

10. Perhitungan *performance* pada *TBO* (3.600 *hours*) pada ketinggian 13.500 *ft* berdasarkan data *aircraft flight log*. Tabel 1.11 merupakan parameter *input engine TBO* 3.600 *hours*.

Tabel 1.11 Parameter *Input Engine TBO* 3600 *hours*

Parameter	*Input*	Satuan
T_0	497,07	^0R
Tt_4	1.751,67	^0R

Perhitungan:

1) Menghitung konstanta gas di kompresor:

$$R_c = \frac{\gamma_c - 1}{\gamma_c} C_{pc}$$

$$R_c = \frac{1{,}4 - 1}{1{,}4} 0{,}24$$

$$R_c = 0{,}06857 \; BTU/lbm.°R$$

$$R_c = 0{,}06857 \; x \; 778{,}16 \; ft.lbf/lbm.°R$$

$$R_c = 53{,}35954 \; ft.lbf/lbm.°R$$

2) Menghitung konstanta gas di t*urbine*:

$$R_t = \frac{\gamma_t - 1}{\gamma_t} C_{pt}$$

$$R_t = \frac{1{,}3-1}{1{,}3} 0{,}276 = 0{,}63692 \; BTU/lbm.°R$$

$$R_t = 0{,}63692 \; x \; 778{,}16 \; ft.lbf/bm.°R$$

$$R_t = 49{,}56281 \; ft.lbf/bm.°R$$

3) Menghitung *Sound Speed* atau kecepatan suara:

$$a_0 = \sqrt{\gamma_c \, R_c \, g_c \, T_0}$$

$$a_0 = \sqrt{1{,}4 \text{ x } 53{,}35954 \; x \; 32{,}174 \; x \; 497{,}07}$$

$a_0 = 1.093{,}028216\ ft/sec$

4) Menghitung *Absolute velocity*:

V_0= TAS=$(\frac{FL}{1.000}\ x\ 2\%\ x\ 0{,}98\ x\ IAS) + IAS$

V_0= $(\frac{13500}{1000}\ x\ 2\%\ x\ 0{,}98\ x\ 125) + 125$

V_0= $158{,}075\ knot$

V_0= $158{,}075\ NM/hr$

V_0= $158{,}075\ x\ 1{,}852\ km/hr$

V_0= $292{,}755\ km/hr$

V_0= $81{,}321\ m/sec$

V_0= $81{,}321 x\ 3{,}2808 = 266{,}77425\ ft/sec$

5) Menghitung $Ratio\ Temperature\ Ram$:

$$\tau_r = 1 + \frac{\gamma_c - 1}{2} M_0^2$$

$dimana$:

$M_0 = V_0/a_0$

$M_0 = \frac{266{,}77425}{1.093{,}028216} = 0{,}244069\ Mach$

$$\tau_r = 1 + \frac{1{,}4 - 1}{2} 0{,}244069^{\ 2}$$

$\tau_r = 1{,}012$

6) Menghitung $Ram\ Pressure\ Ratio$:

$\pi_r = \tau_r{}^{\gamma_c/\ (\gamma_c - 1)}$

$\pi_r = 1{,}012^{1{,}4/\ (1{,}4-1)} = 1{,}042$

7) Menghitung *Inlet Pressure Ratio:*

$\pi_d = \pi_{dmax}\ x\ \eta_r$

Dimana:

η_r= 1 untuk $M_0 \leq 1$

$$\eta_r = 1 - 0{,}0075(M_0 - 1)^{1{,}35} \text{ untuk } M_0 \geq 1$$

$$\pi_d = 0{,}97\ x\ 1 = 0{,}97$$

8) Menghitung *entalphy ratio* di ruang bakar dengan *ambient temperature* pada ketinggian terbang:

$$\tau_\lambda = \frac{C_{pt}\ x\ T_{t4}}{C_{pc}T_0}$$

$$\tau_\lambda = \frac{0{,}276\ x 1.751{,}67}{0{,}24\ x\ 497{,}07} = 4{,}05259$$

9) Menghitung *temperature ratio* di ruang bakar dengan *ambient temperature* pada ketinggian terbang :

$$\tau_c = \pi_c{}^{(\gamma_c - 1)/\ (\gamma_c\ \varepsilon_c)}$$

$$\tau_c = 7^{(1{,}4-1)/\ (1{,}4\ x\ 0{,}90)} = 1{,}85475$$

10) Menghitung *Compressor Efficiency*:

$$\eta_c = \frac{\pi_c{}^{(\gamma_c - 1)/\gamma_c} - 1}{\tau_c - 1}$$

$$\eta_c = \frac{7^{(1{,}4-1)/1{,}4} - 1}{1{,}85475 - 1} = 0{,}87$$

11) Menghitung *Fuel/Air Ratio:*

$$f = \frac{\tau_\lambda - \tau_r\tau_c}{\eta_b h_{PR}/(C_{pc}T_0) - \tau_\lambda}$$

$$f = \frac{4{,}05259 - 1{,}012\ x\ 1{,}85475}{0{,}99\ x\ 18.400/(0{,}24\ x\ 497{,}07) - 4{,}05259} = 0{,}01464$$

12) Menghitung *High Temperature Turbine*:

$$\tau_{tH} = 1 - \frac{\tau_r(\tau_c - 1)}{\eta_{mH}(1 + f)\tau_\lambda}$$

$$\tau_{tH} = 1 - \frac{1{,}012\ (1{,}85475 - 1)}{0{,}99(1 + 0{,}01464)4{,}05259} = 0{,}788$$

13) Menghitung *Turbine High Temperature Ratio*:

$$\pi_{tH} = \tau_{tH}^{\gamma_t/[(\gamma_t-1)e_{tH}]}$$

$$\pi_{tH} = 0{,}788^{\frac{1,3}{(1,3-1)0,89}} = 0{,}313$$

14) Menghitung *Turbine Low Temperature Ratio*:

$$\tau_{tLi}^{*} = \frac{\tau_{tH}^{-1/e_{tH}}}{\pi} + A$$

Dimana

$$\pi = (\pi_r \pi_d \pi_c \pi_b \pi_n)^{(\gamma_t-1)/\,\gamma_t}$$

dan

$$A = \frac{\left[\frac{\gamma_c - 1}{2}\right]\left[\frac{M_0^2}{(\tau_\lambda\, \tau_{tH})}\right]}{(\eta_{prop}\eta_g\eta_{mL})^2}$$

$maka$:

$$\pi = (1{,}042\ x\ 0{,}97\ x\ 7\ x\ 0{,}96\ x\ 0{,}99)^{(1,3-1)/\,1,3} = 1{,}552$$

dan

$$A = \frac{\left[\frac{1,4 - 1}{2}\right]\left[\frac{0,244069\ ^2}{(4,05259\ x\ 0,788)}\right]}{(0{,}83x\ 0{,}99\ x\ 0{,}99)^2} = 3{,}733\ x\ 10^{-3}$$

Selanjutnya nilai τ_{tLi}^{*} dilakukan iterasi sampai nilainya mendekati 0,0001.

$$\tau_{tLi}^{*} = \frac{0{,}788^{-1/0,89}}{1{,}552} + 3{,}733\ x\ 10^{-3} = 0{,}846$$

$$\tau_{tLx} = \frac{\tau_{tH}^{-1/e_{tH}}}{\pi}\tau_{tLi}^{-(1-e_{tL})/e_{tL}} + A(1 + \frac{1 - e_{tL}}{e_{tL}}\frac{\tau_{tH}^{-1/e_{tH}}\ \tau_{tLi}^{-1/e_{tL}}}{\pi})^2$$

$$\tau_{tLx} = \frac{0{,}788^{-1/0,89}}{1{,}552}0{,}846^{-(1/0,91)/0,91} +$$

$$3{,}733\ x\ 10^{-3}(1 + \frac{1 - 0{,}91}{0{,}91}\frac{0{,}788^{-1/0,89}x\ 0{,}846^{-1/0,91}}{1{,}552})^2$$

$$\tau_{tLx} = 0{,}861$$

$$\tau_{tLxx} = \frac{\tau_{tH}^{-1/e_{tH}}}{\pi} \tau_{tLx}^{-(1-e_{tL})/e_{tL}} + A(1 + \frac{1-e_{tL}}{e_{tL}} \frac{\tau_{tH}^{-1/e_{tH}}\ \tau_{tLx}^{-1/e_{tL}}}{\pi})^2$$

$$\tau_{tLxx} = \frac{0{,}788^{-1/0{,}89}}{1{,}552} 0{,}861^{-(1/0{,}91)/0{,}91} +$$

$$3{,}733\ x\ 10^{-3}(1 + \frac{1-0{,}91}{0{,}91} \frac{0{,}788^{-1/0{,}89} x\ 0{,}861^{-1/0{,}91}}{1{,}552})^2$$

$$\tau_{tLxx} = 0{,}85949$$

$$\tau_{tLxxx} = \frac{\tau_{tH}^{-1/e_{tH}}}{\pi} \tau_{tLxx}^{-(1-e_{tL})/e_{tL}} + A(1 + \frac{1-e_{tL}}{e_{tL}} \frac{\tau_{tH}^{-1/e_{tH}}\ \tau_{tLxx}^{-1/e_{tL}}}{\pi})^2$$

$$\tau_{tLxxx} = \frac{0{,}788^{-1/0{,}89}}{1{,}552} 0{,}85949^{-(1/0{,}91)/0{,}91} +$$

$$3{,}733\ x\ 10^{-3}(1 + \frac{1-0{,}91}{0{,}91} \frac{0{,}788^{-1/0{,}89} x\ 0{,}85949^{-1/0{,}91}}{1{,}552})^2$$

$$\tau_{tLxxx} = 0{,}85964$$

$\tau_{tLxxx} - \tau_{tLxx} = 0{,}85964 - 0{,}85949 = 0{,}00015$ telah terpenuhi iterasi.

Sehingga nilai *Turbine Low Temperature Ratio* (τ^*_{tLi}) sebesar 0,85964

15) Menghitung *Turbine Low Pressure Ratio*:

$$\pi_{tL} = \tau_{tL}^{\frac{\gamma_t}{\gamma_t - 1 e_{tL}}}$$

$$\pi_{tL} = 0{,}85964^{\frac{1{,}3}{(1{,}3-1)0{,}91}} = 0{,}487$$

16) Menghitung *Ratio Total Pressure dan Overall Pressure*:

$$\frac{P_{t9}}{P_0} = \pi_r \pi_d \pi_c \pi_b \pi_{tH} \pi_{tL} \pi_n$$

$$\frac{P_{t9}}{P_0} = 1{,}041 x\ 0{,}97\ x\ 7\ x\ 0{,}96\ x\ 0{,}313\ x\ 0{,}487 x\ 0{,}99$$

$$\frac{P_{t9}}{P_0} = 1{,}023$$

17) Menghitung rasio kecepatan aliran udara di *nozzle* dan *Sound Speed*:

$$\frac{V_9}{a_0} = \sqrt{\frac{2\tau_\lambda \tau_{tH} \tau_{tL}}{\gamma_c - 1}[1 - \left(\frac{P_{t9}}{P_9}\right)^{-(\gamma_t - 1)/\gamma_t}]}$$

dimana:

$$\frac{P_{t9}}{P_9} = \left(\frac{\gamma_t + 1}{2}\right)^{\gamma_t/(\gamma_t - 1)}$$

Maka:

$$\frac{P_{t9}}{P_9} = \left(\frac{1,3 + 1}{2}\right)^{1,3/(1,3-1)} = 1,832$$

$$\frac{P_0}{P_9} = \frac{\frac{P_{t9}}{P_9}}{\frac{P_{t9}}{P_0}} = \frac{1,832}{1,023} = 1,791$$

Sehingga:

$$\frac{V_9}{a_0} = \sqrt{\frac{2\ x\ 4,05259\ x\ 0,788\ x\ 0,85964}{1,4 - 1}[1 - (1,832)^{-(1,3-1)/1,3}]}$$

$$\frac{V_9}{a_0} = 1,338$$

18) Menghitung Koefisien Kerja *Output Propeller*:

$$C_{prop} = \eta_{prop} \eta_g \eta_{mL} (1 + f) \tau_\lambda \tau_{tH} (1 - \tau_{tL})$$

$$C_{prop} = 0,83x\ 0,99\ x\ 0,99x(1 + 0,01464)\ 4,05259\ x\ 0,788\ (1 - 0,85964)$$

$$C_{prop} = 0,37$$

19) Menghitung Koefisien Kerja *Compressor Core:*

$$C_c = (\gamma_c - 1)M_0[(1 + f)\frac{V_9}{a_0} - M_0 + (1 + f)\frac{R_t}{R_c}\frac{\frac{T_9}{T_0}}{\frac{V_9}{a_0}} - \frac{1 - \frac{P_0}{P_9}}{\gamma_c}$$

dimana:

$$\frac{T_9}{T_0} = \frac{\frac{T_{t9}}{T_0}}{\left(\frac{P_{t9}}{P_9}\right)^{(\gamma_t - 1)/\gamma_t}}$$

dan

$$\frac{T_{t9}}{T_0} = \frac{T_{t4}}{T_0} \tau_{tH} \tau_{tL}$$

$$\frac{T_{t9}}{T_0} = \frac{1.751,67}{497,07} 0,788 x\ 0,85964 = 2,386$$

Maka:

$$\frac{T_9}{T_0} = \frac{2,386}{(1,832)^{(1,3-1)}/_{1,3}} = 2,075$$

Sehingga:

$$C_c = (1,4-1)0,244069\ \ [(1+0,014642)1,338 - 0,244069 + (1+0,014642)\frac{49,56281}{53,35954}\frac{2,386}{1,338} - \frac{1-1,791}{1,4}$$

$$C_c = 0,02805$$

20) Menghitung koefisien kerja *output* pada *engine core total:*

$$C_{tot} = C_{prop} + C_c$$

$$C_{tot} = 0,37 + 0,02805$$

$$C_{tot} = 0,398$$

21) Menghitung *Thrust and Mass Flow Ratio*:

$$\frac{F}{\dot{m}_0} = \frac{C_{tot} C_{pc} T_0}{V_0}$$

$$\frac{F}{\dot{m}_0} = \frac{0,398\ x\ 0,24\ x\ 497,07}{266,77425}$$

$$\frac{F}{\dot{m}_0} = 233,615\ lbf/(lbm/sec)$$

22) Menghitung *Specific Fuel Consumption:*

$$S = \frac{f}{F/_{\dot{m}_0}}$$

$$S = \frac{0,01464\ x\ 3600}{233,615} = 0,22556\ (lbm/hr)/lbf$$

23) Menghitung *Specific Power*:

$$\frac{\dot{W}}{\dot{m}_0} = C_{tot}C_{pc}T_0$$

$$\frac{\dot{W}}{\dot{m}_0} = 0,398x\ 0,24\ x\ 497,07$$

$$\frac{\dot{W}}{\dot{m}_0} = 47,456\ hp/(lbm/sec)$$

24) Menghitung *Efficiency Thermal*, *Propulsive*, *Overall*

$$\eta T = \frac{0,398}{\frac{0,014637x\ 18.400}{0,276x497,07}} = 17,6\%$$

$$\eta P = \frac{0,398}{\left(\frac{0,37}{0,83}\right) + \left(\frac{1,4-1}{2}\right)x\ (1+0,014637)x\ [(1,338)^2 - 0,2440069^2]}$$

$$\eta P = 49,9\%$$

$$\eta O = 17,6\%\ x\ 49,9\% = 8,8\%$$

11. Perhitungan *performance* setelah *TBO Extension* (5.600 *hours*) pada ketinggian 4.500 ft berdasarkan data *Aircraft Flight Log (AFL)* yang di *record* di Nabire pada 28 Juni 2017. Tabel 1.12 merupakan parameter *input engine TBO extension* 5.600 *hours*.

Tabel 1.12 Parameter *Input Engine Extension* 5600 *Hours.*

Parameter	***Input***	**Satuan**
T_0	527,67	^{0}R
Tt_4	1.733,67	^{0}R

Perhitungan:

1) Menghitung konstanta gas di kompresor:

$$R_c = \frac{\gamma_c - 1}{\gamma_c} C_{pc}$$

$$R_c = \frac{1,4 - 1}{1,4} 0,24$$

$$R_c = 0,06857\ BTU/lbm.°R$$

$$R_c = 0,06857\ x\ 778,16\ ft.lbf/lbm.°R$$

$$R_c = 53,35954\ ft.lbf/lbm.°R$$

2) Menghitung konstanta gas di *turbine*:

$$R_t = \frac{\gamma_t - 1}{\gamma_t} C_{pt}$$

$$R_t = \frac{1,3-1}{1,3} 0,276 = 0,63692\ BTU/lbm.°R$$

$$R_t = 0,63692\ x\ 778,16\ ft.lbf/lbm.°R$$

$$R_t = 49,56281\ ft.lbf/lbm.°R$$

3) Menghitung *Sound Speed* atau kecepatan suara:

$$a_0 = \sqrt{\gamma_c\ R_c\ g_c\ T_0}$$

$$a_0 = \sqrt{1,4\ \text{x}\ 53,35954\ x\ 32,174\ x\ 527,67}$$

$$a_0 = 1.126,1696\ ft/sec$$

4) Menghitung *Absolute velocity*:

V_0= TAS=$(\frac{FL}{1000}\ x\ 2\%\ x\ 0,98\ x\ IAS) + IAS$

V_0= $(\frac{4500}{1000}\ x\ 2\%\ x\ 0,98\ x\ 147) + 147$

V_0= $159,9654\ knot$

V_0= $159,9654\ x\ 0,5144 = 82,2862\ m/sec$

V_0= $82,2862\ x\ 3,2808 = 269,9646 ft/sec$

5) Menghitung $Ratio\ Temperature\ Ram$:

$$\tau_r = 1 + \frac{\gamma_c - 1}{2} M_0^2$$

$$M_0 = \frac{269,9646}{1126,16959} = 0,239719\ Mach$$

$$\tau_r = 1 + \frac{1,4-1}{2} 0,239719^2$$

$$\tau_r = 1,01149$$

6) Menghitung *Ram Pressure Ratio*:

$$\pi_r = \tau_r^{\gamma_c/\,(\gamma_c - 1)}$$

$$\pi_r = 1,01149^{1,4/\,(1,4-1)} = 1,04081$$

7) Menghitung *Inlet Pressure Ratio:*

$$\pi_d = \pi_{dmax}\ x\ \eta_r$$

Dimana:

η_r= 1 untuk $M_0 \leq 1$

$\eta_r = 1 - 0,0075(M_0 - 1)^{1,35}$ untuk $M_0 \geq 1$

$$\pi_d = 0,97\ x\ 1 = 0,97$$

8) Menghitung *entalphy ratio* di ruang bakar dengan *ambient temperature* pada ketinggian terbang:

$$\tau_\lambda = \frac{C_{pt}\ x\ T_{t4}}{C_{pc} T_0}$$

$$\tau_\lambda = \frac{0,276\ x\ 1.733,67}{0,24\ x\ 527,67} = 3,77835$$

9) Menghitung *temperature ratio* di ruang bakar dengan *ambient temperature* pada ketinggian terbang:

$$\tau_c = \pi_c^{(\gamma_c - 1)/\,(\gamma_c\ \varepsilon_c)}$$

$$\tau_c = 7^{(1,4-1)/\,(1,4\ x\ 0,90)} = 1,85475$$

10) Menghitung *Compressor Efficiency*:

$$\eta_c = \frac{\pi_c{}^{(\gamma_c - 1)/\gamma_c} - 1}{\tau_c - 1}$$

$$\eta_c = \frac{7^{\,(1,4-1)/1,4} - 1}{1,854748 - 1} = 0,87001$$

11) Menghitung *Fuel/Air Ratio:*

$$f = \frac{\tau_\lambda - \tau_r \tau_c}{\eta_b h_{PR}/(C_{pc} T_0) - \tau_\lambda}$$

$$f = \frac{3,77835 - 1,01149\ x\ 1,85475}{0,99\ x\ 18.400/(0,24\ x\ 527,67) - \ 3,77835} = 0,01358$$

12) Menghitung *High Temperature Turbine*:

$$\tau_{tH} = 1 - \frac{\tau_r(\tau_c - 1)}{\eta_{mH}(1 + f)\tau_\lambda}$$

$$\tau_{tH} = 1 - \frac{1,01149\ (1,85475 - 1)}{0,99(1 + 0,01358)\ 3,77835} = 0,77196$$

13) Menghitung *Turbine High Temperature Ratio*:

$$\pi_{tH} = \ \tau_{tH}^{\gamma_t/[(\gamma_t - 1)e_{tH}]}$$

$$\pi_{tH} = \ 0,77196^{\frac{1,3}{(1,3-1)0,89}} = 0,28361$$

14) Menghitung *Turbine Low Temperature Ratio*:

$$\tau_{tLi}^{*} = \ \frac{\tau_{tH}^{-1/e_{tH}}}{\pi} + A$$

$$\pi = (\pi_r \pi_d \pi_c \pi_b \pi_n)^{(\gamma_t - 1)/\ \gamma_t}$$

$$A = \frac{\left[\frac{\gamma_c - 1}{2}\right]\left[\frac{M_0^2}{(\tau_\lambda\ \tau_{tH})}\right]}{(\eta_{prop}\eta_g\eta_{mL})^2}$$

$$\pi = (1,040581\ x\ 0,97\ x\ 7\ x\ 0,96\ x\ 0,99)^{(1,3-1)/\ 1,3} = 1,55196$$

$$A = \frac{\left[\frac{1,4-1}{2}\right]\left[\frac{0,239719^{\ 2}}{(3,77835\ x\ 0,77196)}\right]}{(0,83x\ 0,99\ x\ 0,99)^2} = 3,94x\ 10^{-3}$$

Untuk menghitung τ_{tLi}^{*} dilakukan iterasi sampai nilainya mendekati 0,0001.

$$\tau_{tLi}^{*} = \frac{0,77196^{-1/0,89}}{1,55196} + 3,94x\ 10^{-3} = 0,86576$$

$$\tau_{tLx} = \frac{\tau_{tH}^{-1/e_{tH}}}{\pi}\tau_{tLi}^{-(1-e_{tL})/e_{tL}} + A(1 + \frac{1-e_{tL}}{e_{tL}}\frac{\tau_{tH}^{-1/e_{tH}}\ \tau_{tLi}^{-1/e_{tL}}}{\pi})^2$$

$$\tau_{tLx} = \frac{0,77196^{-1/0,89}}{1,55196}0,86576^{-(1/0,91)/0,91} +$$

$$3,94\ 10^{-3}(1 + \frac{1-0,91}{0,91}\frac{0,77196^{-1/0,89}x\ 0,86576^{-1/0,91}}{1,55196})^2$$

$$\tau_{tLx} = 0,87896$$

$$\tau_{tLxx} = \frac{\tau_{tH}^{-1/e_{tH}}}{\pi}\tau_{tLx}^{-(1-e_{tL})/e_{tL}} + A(1 + \frac{1-e_{tL}}{e_{tL}}\frac{\tau_{tH}^{-1/e_{tH}}\ \tau_{tLx}^{-1/e_{tL}}}{\pi})^2$$

$$\tau_{tLxx} = \frac{0,77196^{-1/0,89}}{1,55196}0,87896^{-(1/0,91)/0,91} +$$

$$3,94\ 10^{-3}(1 + \frac{1-0,91}{0,91}\frac{0,77196^{-1/0,89}x\ 0,87896^{-1/0,91}}{1,55196})^2$$

$$\tau_{tLxx} = 0,87764$$

$$\tau_{tLxxx} = \frac{\tau_{tH}^{-1/e_{tH}}}{\pi}\tau_{tLxx}^{-(1-e_{tL})/e_{tL}} + A(1 + \frac{1-e_{tL}}{e_{tL}}\frac{\tau_{tH}^{-1/e_{tH}}\ \tau_{tLxx}^{-1/e_{tL}}}{\pi})^2$$

$$\tau_{tLxxx} = \frac{0,77196^{-1/0,89}}{1,55196}0,87764^{-(1/0,91)/0,91} +$$

$$3,94\ 10^{-3}(1 + \frac{1-0,91}{0,91}\frac{0,77196^{-1/0,89}x\ 0,87764^{-1/0,91}}{1,55196})^2$$

$$\tau_{tLxxx} = 0,87777$$

$\tau_{tLxx} - \tau_{tLxxx} = 0,87764 - 0,87777 = 0,00013$ telah terpenuhi iterasi.

Sehingga nilai *Turbine Low Temperature Ratio* (τ_{tLi}^{*}) sebesar $0,87777$

15) Menghitung *Turbine Low Pressure Ratio*:

$$\pi_{tL} = \tau_{tL}^{\frac{\gamma\ \ t}{\gamma_{t-1}e_{tL}}}$$

$$\pi_{tL} = 0{,}87777^{\frac{1{,}3}{(1{,}3-1)0{,}91}} = 0{,}53751$$

16) Menghitung *Ratio Total Pressure dan Overall Pressure*:

$$\frac{P_{t9}}{P_0} = \pi_r \pi_d \pi_c \pi_b \pi_{tH} \pi_{tL} \pi_n$$

$$\frac{P_{t9}}{P_0} = 1{,}04053\ x\ 0{,}97\ x\ 7\ x\ 0{,}96\ x\ 0{,}27324\ x\ 0{,}55829 x\ 0{,}99$$

$$\frac{P_{t9}}{P_0} = 1{,}02388$$

$$\frac{P_{t9}}{P_9} = \left(\frac{\gamma_t + 1}{2}\right)^{\gamma_{t/(\gamma_t - 1)}}$$

$$\frac{P_{t9}}{P_9} = \left(\frac{1{,}3 + 1}{2}\right)^{1{,}3/(1{,}3-1)} = 1{,}83242$$

$$\frac{P_0}{P_9} = \frac{\frac{P_{t9}}{P_9}}{\frac{P_{t9}}{P_0}} = \frac{1{,}83242}{1{,}0243} = 1{,}78968$$

17) Menghitung rasio kecepatan aliran udara di *nozzle* dan *Sound Speed*:

$$\frac{V_9}{a_0} = \sqrt{\frac{2\tau_\lambda \tau_{tH} \tau_{tL}}{\gamma_c - 1}[1 - \left(\frac{P_{t9}}{P_9}\right)^{-(\gamma_t - 1)/\gamma_t}]}$$

$$\frac{V_9}{a_0} = \sqrt{\frac{2\ x\ 3{,}77835\ x\ 0{,}77196\ x\ 0{,}87777}{1{,}4 - 1}[1 - (1{,}83242)^{-(1{,}3-1)/1{,}3}]}$$

$$\frac{V_9}{a_0} = 1{,}279217$$

18) Menghitung Koefisien Kerja *Output Propeller*:

$$C_{prop} = \eta_{prop} \eta_g \eta_{mL} (1 + f) \tau_\lambda \tau_{tH} (1 - \tau_{tL})$$

$$C_{prop} = 0,83\ x\ 0,99\ x\ 0,99x\ (1 + 0,01358\ )\ 3,77835\ x\ 0,77196\ (1 - 0,87777)$$

$$C_{prop} = 0,29109$$

19) Menghitung Koefisien Kerja *Compressor Core:*

$$C_c = (\gamma_c - 1)M_0[(1+f)\frac{V_9}{a_0} - M_0 + (1+f)\frac{R_t}{R_c}\frac{\frac{T_9}{T_0}}{\frac{V_9}{a_0}} - \frac{1 - \frac{P_0}{P_9}}{\gamma_c}$$

$$\frac{T_{t9}}{T_0} = \frac{T_{t4}}{T_0}\tau_{tH}\tau_{tL}$$

$$\frac{P_0}{P_9} = 1,78968$$

$$\frac{T_{t9}}{T_0} = \frac{1733,67}{527,67}0,77196\ x\ 0,87777 = 2,22629$$

$$\frac{T_9}{T_0} = \frac{\frac{T_{t9}}{T_0}}{\left(\frac{P_{t9}}{P_9}\right)^{(\gamma_t - 1)/\gamma_t}} = \frac{2,22629}{(1,83242)^{(1,3-1)/1,3}} = 1,9359$$

$$C_c = (1,4 - 1)0,239719\ [(1 + 0,01358)1,27645 - 0,239719 + (1 + 0,01358)\frac{49,56281}{53,35954}\frac{1,9359}{1,279217} - \frac{1 - 1,78968}{1,4}$$

$$C_c = 0,025631$$

20) Menghitung koefisien kerja *output* pada *engine core total:*

$$C_{tot} = C_{prop} + C_c$$

$$C_{tot} = 0,29109 + 0,025631$$

$$C_{tot} = 0,31741$$

21) Menghitung *Thrust and Mass Flow Ratio*:

$$\frac{F}{\dot{m}_0} = \frac{C_{tot}C_{pc}T_0}{V_0}$$

$$\frac{F}{\dot{m}_0} = \frac{0,31741\ x\ 0,24\ x\ 527,67}{269,9646}$$

$$\frac{F}{\dot{m}_0} = 195{,}5387\ lbf/(lbm/sec)$$

22) Menghitung *Specific Fuel Consumption:*

$$S = \frac{f}{F/_{\dot{m}_0}}$$

$$S = \frac{0{,}01358}{195{,}5387} = 0{,}257005\ (lbm/hr)/lbf$$

23) Menghitung *Specific Power*:

$$\frac{\dot{W}}{\dot{m}_0} = C_{tot}C_{pc}T_0$$

$$\frac{\dot{W}}{\dot{m}_0} = 0{,}31741\ x\ 0{,}24\ x\ 527{,}67$$

$$\frac{\dot{W}}{\dot{m}_0} = 40{,}55917\ hp/(lbm/sec)$$

24) Menghitung *Efficiency Thermal*, *Propulsive*, *Overall*

$$\eta T = \frac{0{,}31741}{\frac{0{,}01358x\ 18.400}{0{,}276x527{,}67}} = 16{,}1\%$$

$$\eta P = \frac{0{,}31741}{\left(\frac{0{,}29109}{0{,}83}\right) + \left(\frac{1{,}4-1}{2}\right)x\ (1+0{,}01358)x\ [(1{,}279217)^2 - 0{,}239719^2]}$$

$$\eta P = 46{,}8\%$$

$$\eta O = 16{,}1\%\ x\ 46{,}8\% = 7{,}5\%$$

12. Perhitungan *performance* setelah *TBO Extension* (5.600 *hours*) pada ketinggian 5.500 ft berdasarkan data *Aircraft Flight Log (AFL)*. Tabel 1.13 merupakan parameter *input engine TBO extension* 5.600 *hours*.

Tabel 1.13 Parameter *Input Engine TBO* 3600 *hours*

Parameter	*Input*	Satuan
T_0	522,27	^0R
Tt_4	1.724,67	^0R

Perhitungan:

1) Menghitung konstanta gas di kompresor:

$$R_c = \frac{\gamma_c - 1}{\gamma_c} C_{pc}$$

$$R_c = \frac{1{,}4 - 1}{1{,}4} 0{,}24$$

$$R_c = 0{,}06857\ BTU/lbm.°R$$

$$R_c = 0{,}06857\ x\ 778{,}16\ ft.lbf/lbm.°R$$

$$R_c = 53{,}35954\ ft.lbf/lbm.°R$$

2) Menghitung konstanta gas di t*urbine*:

$$R_t = \frac{\gamma_t - 1}{\gamma_t} C_{pt}$$

$$R_t = \frac{1{,}3-1}{1{,}3} 0{,}276 = 0{,}63692\ BTU/lbm.°R$$

$$R_t = 0{,}63692\ x\ 778{,}16\ ft.lbf/bm.°R$$

$$R_t = 49{,}56281\ ft.lbf/bm.°R$$

3) Menghitung *Sound Speed* atau kecepatan suara:

$$a_0 = \sqrt{\gamma_c\ R_c\ g_c\ T_0}$$

$$a_0 = \sqrt{1{,}4\ \text{x}\ 53{,}35954\ x\ 32{,}174\ x\ 522{,}27}$$

$$a_0 = 1.120{,}39235\ ft/sec$$

4) Menghitung *Absolute velocity*:

$$V_0 = TAS = (\frac{FL}{1.000}\ x\ 2\%\ x\ 0{,}98\ x\ IAS) + IAS$$

$$V_0 = (\frac{5500}{1000}\ x\ 2\%\ x\ 0{,}98\ x\ 140) + 140$$

$$V_0 = 155{,}092\ knot$$

$$V_0 = 155{,}092\ NM/hr$$

$V_0 = 155{,}092\ x\ 1{,}852\ km/hr$

$V_0 = 287{,}23\ km/hr$

$V_0 = 79{,}786\ m/sec$

$V_0 = 79{,}786 x\ 3{,}2808 = 261{,}74\ ft/sec$

5) Menghitung *Ratio Temperature Ram*:

$$\tau_r = 1 + \frac{\gamma_c - 1}{2} M_0^2$$

dimana:

$M_0 = V_0/a_0$

$M_0 = \frac{261{,}74}{1.120{,}39235} = 0{,}233615\ Mach$

$$\tau_r = 1 + \frac{1{,}4 - 1}{2} 0{,}233615^{\ 2}$$

$\tau_r = 1{,}01092$

6) Menghitung *Ram Pressure Ratio*:

$\pi_r = \tau_r{}^{\gamma_c/\ (\gamma_c - 1)}$

$\pi_r = 1{,}01092^{1{,}4/\ (1{,}4-1)} = 1{,}013873$

7) Menghitung *Inlet Pressure Ratio:*

$\pi_d = \pi_{dmax}\ x\ \eta_r$

Dimana:

$\eta_r = 1$ untuk $M_0 \leq 1$

$\eta_r = 1 - 0{,}0075(M_0 - 1)^{1{,}35}$ untuk $M_0 \geq 1$

$\pi_d = 0{,}97\ x\ 1 = 0{,}97$

8) Menghitung *entalphy ratio* di ruang bakar dengan *ambient temperature* pada ketinggian terbang:

$$\tau_\lambda = \frac{C_{pt}\ x\ T_{t4}}{C_{pc} T_0}$$

$$\tau_\lambda = \frac{0,276\ x 1.724,67}{0,24\ x\ 522,27} = 3,7976$$

9) Menghitung *temperature ratio* di ruang bakar dengan *ambient temperature* pada ketinggian terbang :

$$\tau_c = {\pi_c}^{(\gamma_c - 1)/\ (\gamma_c\ \varepsilon_c)}$$

$$\tau_c = 7^{(1,4-1)/\ (1,4\ x\ 0,90)} = 1,85475$$

10) Menghitung *Compressor Efficiency*:

$$\eta_c = \frac{{\pi_c}^{(\gamma_c - 1)/\gamma_c} - 1}{\tau_c - 1}$$

$$\eta_c = \frac{7^{(1,4-1)/1,4} - 1}{1,85475 - 1} = 0,87001$$

11) Menghitung *Fuel/Air Ratio:*

$$f = \frac{\tau_\lambda - \tau_r \tau_c}{\eta_b h_{PR}/(C_{pc} T_0) - \tau_\lambda}$$

$$f = \frac{3,7976 - 1,012\ x\ 1,85475}{0,99\ x\ 18.400/(0,24\ x\ 522,27) - 3,7976} = 0,013584$$

12) Menghitung *High Temperature Turbine*:

$$\tau_{tH} = 1 - \frac{\tau_r(\tau_c - 1)}{\eta_{mH}(1 + f)\tau_\lambda}$$

$$\tau_{tH} = 1 - \frac{1,012\ (1,85475 - 1)}{0,99(1 + 0,013584)3,7976} = 0,77325$$

13) Menghitung *Turbine High Temperature Ratio*:

$$\pi_{tH} = \ \tau_{tH}^{\gamma_{t/[(\gamma_t - 1)e_{tH}]}}$$

$$\pi_{tH} = \ 0,77325^{\frac{1,3}{(1,3-1)0,89}} = 0,28591$$

14) Menghitung *Turbine Low Temperature Ratio*:

$$\tau_{tLi}^{*} = \frac{\tau_{tH}^{-1/e_{tH}}}{\pi} + A$$

Dimana

$$\pi = (\pi_r \pi_d \pi_c \pi_b \pi_n)^{(\gamma_t - 1)/\ \gamma_t}$$

dan

$$A = \frac{\left[\frac{\gamma_c - 1}{2}\right]\left[\frac{M_0^2}{(\tau_\lambda\, \tau_{tH})}\right]}{(\eta_{prop}\eta_g \eta_{mL})^2}$$

$maka$:

$$\pi = (1{,}03873\ x\ 0{,}97\ x\ 7\ x\ 0{,}96\ x\ 0{,}99)^{(1{,}3-1)/\ 1{,}3} = 1{,}55124$$

dan

$$A = \frac{\left[\frac{1{,}4 - 1}{2}\right]\left[\frac{0{,}233615\ ^2}{(3{,}7976\ x\ 0{,}77325)}\right]}{(0{,}83x\ 0{,}99\ x\ 0{,}99)^2} = 3{,}72\ x\ 10^{-3}$$

Selanjutnya nilai τ_{tLi}^{*} dilakukan iterasi sampai nilainya mendekati 0,0001.

$$\tau_{tLi}^{*} = \frac{0{,}77325^{-1/0{,}89}}{1{,}55124} + 3{,}72\ x\ 10^{-3} = 0{,}86432$$

$$\tau_{tLx} = \frac{\tau_{tH}^{-1/e_{tH}}}{\pi}\tau_{tLi}^{-(1-e_{tL})/e_{tL}} + A(1 + \frac{1 - e_{tL}}{e_{tL}}\frac{\tau_{tH}^{-1/e_{tH}}\ \tau_{tLi}^{-1/e_{tL}}}{\pi})^2$$

$$\tau_{tLx} = \frac{0{,}77325^{-1/0{,}89}}{1{,}55124}0{,}86432^{-(1/0{,}91)/0{,}91} +$$

$$3{,}72\ x\ 10^{-3}(1 + \frac{1 - 0{,}91}{0{,}91}\frac{0{,}77325^{-1/0{,}89}x\ 0{,}86432^{-1/0{,}91}}{1{,}55124})^2$$

$$\tau_{tLx} = 0{,}877603$$

$$\tau_{tLxx} = \frac{\tau_{tH}^{-1/e_{tH}}}{\pi}\tau_{tLx}^{-(1-e_{tL})/e_{tL}} + A(1 + \frac{1 - e_{tL}}{e_{tL}}\frac{\tau_{tH}^{-1/e_{tH}}\ \tau_{tLx}^{-1/e_{tL}}}{\pi})^2$$

$$\tau_{tLxx} = \frac{0{,}77325^{-1/0{,}89}}{1{,}55124}0{,}877603^{-(1/0{,}91)/0{,}91} +$$

$$3{,}72\ x\ 10^{-3}(1 + \frac{1 - 0{,}91}{0{,}91}\frac{0{,}77325^{-1/0{,}89}x\ 0{,}877603^{-1/0{,}91}}{1{,}55124})^2$$

$\tau_{tLxx} = 0{,}87627$

$$\tau_{tLxxx} = \frac{\tau_{tH}^{-1/e_{tH}}}{\pi}\tau_{tLxx}^{-(1-e_{tL})/e_{tL}} + A(1 + \frac{1-e_{tL}}{e_{tL}}\frac{\tau_{tH}^{-1/e_{tH}}\ \tau_{tLxx}^{-1/e_{tL}}}{\pi})^2$$

$$\tau_{tLxxx} = \frac{0{,}77325^{-1/0{,}89}}{1{,}55124}0{,}87627^{-(1/0{,}91)/0{,}91} +$$

$$3{,}72\ x\ 10^{-3}(1 + \frac{1-0{,}91}{0{,}91}\frac{0{,}77325^{-1/0{,}89}x\ 0{,}87627^{-1/0{,}91}}{1{,}55124})^2$$

$\tau_{tLxxx} = 0{,}87641$

$\tau_{tLxxx} - \tau_{tLxx} = 0{,}87641 - 0{,}87627 = 0{,}00014$ telah terpenuhi iterasi.

Sehingga nilai *Turbine Low Temperature Ratio* (τ_{tLi}^{*}) sebesar 0,87641

15) Menghitung *Turbine Low Pressure Ratio*:

$$\pi_{tL} = \tau_{tL}^{\frac{\gamma_t}{\gamma_t - 1 e_{tL}}}$$

$$\pi_{tL} = 0{,}87641^{\frac{1{,}3}{(1{,}3-1)0{,}91}} = 0{,}53354$$

16) Menghitung *Ratio Total Pressure dan Overall Pressure*:

$$\frac{P_{t9}}{P_0} = \pi_r\pi_d\pi_c\pi_b\pi_{tH}\pi_{tL}\pi_n$$

$$\frac{P_{t9}}{P_0} = 1{,}041x\ 0{,}97\ x\ 7\ x\ 0{,}96\ x\ 0{,}28591\ x\ 0{,}53354\ x\ 0{,}99$$

$$\frac{P_{t9}}{P_0} = 1{,}02255$$

17) Menghitung rasio kecepatan aliran udara di *nozzle* dan *Sound Speed*:

$$\frac{V_9}{a_0} = \sqrt{\frac{2\tau_\lambda\tau_{tH}\tau_{tL}}{\gamma_c - 1}[1 - \left(\frac{P_{t9}}{P_9}\right)^{-(\gamma_t-1)/\gamma_t}]}$$

dimana:

$$\frac{P_{t9}}{P_9} = \left(\frac{\gamma_t + 1}{2}\right)^{\gamma_{t/(\gamma_t-1)}}$$

Maka:

$$\frac{P_{t9}}{P_9} = \left(\frac{1,3+1}{2}\right)^{1,3/(1,3-1)} = 1,83242$$

$$\frac{P_0}{P_9} = \frac{\frac{P_{t9}}{P_9}}{\frac{P_{t9}}{P_0}} = \frac{1,83242}{1,02255} = 1,79201$$

Sehingga:

$$\frac{V_9}{a_0} = \sqrt{\frac{2\ x\ 3,7976\ x\ 0,77325\ x\ 0,87641}{1,4-1}\left[1-(1,83242)^{-(1,3-1)/1,3}\right]}$$

$$\frac{V_9}{a_0} = 1,29553$$

18) Menghitung Koefisien Kerja *Output Propeller*:

$$C_{prop} = \eta_{prop}\eta_g\eta_{mL}(1+f)\tau_\lambda\tau_{tH}(1-\tau_{tL})$$

$$C_{prop} = 0,83x\ 0,99\ x\ 0,99(1+0,013584)\ 3,7976\ x\ 0,77325\ (1-0,87641)$$

$$C_{prop} = 0,29925$$

19) Menghitung Koefisien Kerja *Compressor Core:*

$$C_c = (\gamma_c - 1)M_0[(1+f)\frac{V_9}{a_0} - M_0 + (1+f)\frac{R_t}{R_c}\frac{\frac{T_9}{T_0}}{\frac{V_9}{a_0}} - \frac{1-\frac{P_0}{P_9}}{\gamma_c}$$

$dimana$:

$$\frac{T_9}{T_0} = \frac{\frac{T_{t9}}{T_0}}{\left(\frac{P_{t9}}{P_9}\right)^{(\gamma_t-1)/\gamma_t}}$$

dan

$$\frac{T_{t9}}{T_0} = \frac{T_{t4}}{T_0}\tau_{tH}\tau_{tL}$$

$$\frac{T_{t9}}{T_0} = \frac{1.724,67}{522,27}0,77325x\ 0,87641 = 2,23787$$

Maka:

$$\frac{T_9}{T_0} = \frac{2,23787}{(1,83242)^{(1,3-1)}/_{1,3}} = 1,94598$$

Sehingga:

$$C_c = (1,4-1)0,233615\ [(1+0,013584)1,29553 - 0,233615 + (1+0,013584)\frac{49,56281}{53,35954}\frac{1,94598}{1,29553} - \frac{1-1,79201}{1,4}$$

$$C_c = 0,02612$$

20) Menghitung koefisien kerja *output* pada *engine core total:*

$$C_{tot} = C_{prop} + C_c$$

$$C_{tot} = 0,29925 + 0,02612$$

$$C_{tot} = 0,32537$$

21) Menghitung *Thrust and Mass Flow Ratio*:

$$\frac{F}{\dot{m}_0} = \frac{C_{tot}C_{pc}T_0}{V_0}$$

$$\frac{F}{\dot{m}_0} = \frac{0,32537\ x\ 0,24\ x\ 522,27}{261,74}$$

$$\frac{F}{\dot{m}_0} = 204,62589\ lbf/(lbm/sec)$$

22) Menghitung *Specific Fuel Consumption:*

$$S = \frac{f}{F/_{\dot{m}_0}}$$

$$S = \frac{0,013584\ x\ 3600}{204,62589} = 0,23899\ (lbm/hr)/lbf$$

23) Menghitung *Specific Power*:

$$\frac{\dot{W}}{\dot{m}_0} = C_{tot}C_{pc}T_0$$

$$\frac{\dot{W}}{\dot{m}_0} = 0,32537\ x\ 0,24\ x\ 522,27$$

$$\frac{\dot{W}}{\dot{m}_0} = 40{,}78318\ hp/(lbm/sec)$$

24) Menghitung *Efficiency Thermal*, *Propulsive*, *Overall*

$$\eta T = \frac{0{,}32537}{\frac{0{,}013584x\ 18.400}{0{,}276x522{,}27}} = 16{,}3\%$$

$$\eta P = \frac{0{,}32537}{\left(\frac{0{,}29925}{0{,}83}\right) + \left(\frac{1{,}4-1}{2}\right) x\ (1 + 0{,}013584) x\ [(1{,}29553)^2 - 0{,}233615^2]}$$

$$\eta P = 47{,}2\%$$

$$\eta O = 16{,}3\%\ x\ 47{,}3\% = 7{,}7\%$$

13. Perhitungan *performance* setelah *TBO Extension* (5.600 *hours*) pada ketinggian 6.500 ft berdasarkan data *Aircraft Flight Log (AFL)*. Tabel 1.14 merupakan parameter *input engine TBO extension* 5.600 *hours*

Tabel 1.14 Parameter *Input Engine TBO* 3600 *hours*

Parameter	*Input*	Satuan
T_0	518,67	^0R
Tt_4	1.724,67	^0R

Perhitungan:

1) Menghitung konstanta gas di kompresor:

$$R_c = \frac{\gamma_c - 1}{\gamma_c} C_{pc}$$

$$R_c = \frac{1{,}4-1}{1{,}4} 0{,}24$$

$$R_c = 0{,}06857\ BTU/lbm.°R$$

$$R_c = 0{,}06857\ x\ 778{,}16\ ft.lbf/lbm.°R$$

$$R_c = 53{,}35954\ ft.lbf/lbm.°R$$

2) Menghitung konstanta gas di t*urbine*:

$$R_t = \frac{\gamma_t - 1}{\gamma_t} C_{pt}$$

$$R_t = \frac{1,3-1}{1,3} 0,276 = 0,63692\ BTU/lbm.°R$$

$$R_t = 0,63692\ x\ 778,16\ \ ft.lbf/bm.°R$$

$$R_t = 49,56281\ \ ft.lbf/bm.°R$$

3) Menghitung *Sound Speed* atau kecepatan suara:

$$a_0 = \sqrt{\gamma_c\, R_c\ \ g_c\, T_0}$$

$$a_0 = \sqrt{1,4\ \text{x}\ \ 53,35954\ x\ 32,174\ x\ 518,67}$$

$$a_0 = 1.116,524425\ ft/sec$$

4) Menghitung *Absolute velocity*:

V_0= TAS=$(\frac{FL}{1.000} x\ 2\%\ x\ 0,98\ x\ IAS) + IAS$

V_0= $(\frac{6500}{1000} x\ 2\%\ x\ 0,98\ x\ 140) + 140$

V_0= $158,963\ knot$

V_0= $158,963\ NM/hr$

V_0= $158,963\ x\ 1,852\ km/hr$

V_0= $294,399\ km/hr$

V_0= $81,778\ m/sec$

V_0= $79,786 x\ 3,2808 = 268,2736\ ft/sec$

5) Menghitung $Ratio\ Temperature\ Ram$:

$$\tau_r = 1 + \frac{\gamma_c - 1}{2} M_0^2$$

$dimana$:

$$M_0 = V_0/a_0$$

$$M_0 = \frac{268,2736}{1.116,524425} = 0,2240276\ Mach$$

$$\tau_r = 1 + \frac{1,4 - 1}{2} 0,2240276^{\,2}$$

$$\tau_r = 1,01155$$

6) Menghitung *Ram Pressure Ratio*:

$$\pi_r = \tau_r^{\gamma_c/\,(\gamma_c - 1)}$$

$$\pi_r = 1,01155^{1,4/\,(1,4-1)} = 1,041$$

7) Menghitung *Inlet Pressure Ratio:*

$$\pi_d = \pi_{dmax}\ x\ \eta_r$$

Dimana:

η_r= 1 untuk $M_0 \leq 1$

$\eta_r = 1 - 0,0075(M_0 - 1)^{1,35}$ untuk $M_0 \geq 1$

$$\pi_d = 0,97\ x\ 1 = 0,97$$

8) Menghitung *entalphy ratio* di ruang bakar dengan *ambient temperature* pada ketinggian terbang:

$$\tau_\lambda = \frac{C_{pt}\ x\ T_{t4}}{C_{pc} T_0}$$

$$\tau_\lambda = \frac{0,276\ x 1.724,67}{0,24\ x\ 518,67} = 3,82395$$

9) Menghitung *temperature ratio* di ruang bakar dengan *ambient temperature* pada ketinggian terbang :

$$\tau_c = \pi_c^{(\gamma_c - 1)/\,(\gamma_c\ \varepsilon_c)}$$

$$\tau_c = 7^{(1,4-1)/\,(1,4\ x\ 0,90)} = 1,85475$$

10) Menghitung *Compressor Efficiency*:

$$\eta_c = \frac{\pi_c^{(\gamma_c - 1)/\gamma_c} - 1}{\tau_c - 1}$$

$$\eta_c = \frac{7^{(1,4-1)/1,4} - 1}{1,85475 - 1} = 0,87001$$

11) Menghitung *Fuel/Air Ratio:*

$$f = \frac{\tau_\lambda - \tau_r \tau_c}{\eta_b h_{PR}/(C_{pc}T_0) - \tau_\lambda}$$

$$f = \frac{3,82395 - 1,01155\ x\ 1,85475}{0,99\ x\ 18.400/(0,24\ x\ 518,67) - 3,82395} = 0,01367$$

12) Menghitung *High Temperature Turbine*:

$$\tau_{tH} = 1 - \frac{\tau_r(\tau_c - 1)}{\eta_{mH}(1+f)\tau_\lambda}$$

$$\tau_{tH} = 1 - \frac{1,01155\ (1,85475 - 1)}{0,99(1 + 0,01367)3,82395} = 0,77469$$

13) Menghitung *Turbine High Temperature Ratio*:

$$\pi_{tH} = \tau_{tH}^{\gamma_t/[(\gamma_t - 1)e_{tH}]}$$

$$\pi_{tH} = 0,77469^{\frac{1,3}{(1,3-1)0,89}} = 0,28852$$

14) Menghitung *Turbine Low Temperature Ratio*:

$$\tau_{tLi}^{*} = \frac{\tau_{tH}^{-1/e_{tH}}}{\pi} + A$$

Dimana

$$\pi = (\pi_r \pi_d \pi_c \pi_b \pi_n)^{(\gamma_t - 1)/\gamma_t}$$

dan

$$A = \frac{\left[\frac{\gamma_c - 1}{2}\right]\left[\frac{M_0^2}{(\tau_\lambda\, \tau_{tH})}\right]}{(\eta_{prop}\eta_g\eta_{mL})^2}$$

$maka$:

$$\pi = (1,03873\ x\ 0,97\ x\ 7\ x\ 0,96\ x\ 0,99)^{(1,3-1)/\,1,3} = 1,55124$$

dan

$$A = \frac{\left[\frac{1,4 - 1}{2}\right]\left[\frac{0,2240276^{\ 2}}{(3,82395\ x\ 0,77469)}\right]}{(0,83x\ 0,99\ x\ 0,99)^2} = 3,9x\ 10^{-3}$$

Selanjutnya nilai τ_{tLi}^{*} dilakukan iterasi sampai nilainya mendekati 0,0001.

$$\tau_{tLi}^{*} = \frac{0{,}77469^{-1/0{,}89}}{1{,}55124} + 3{,}9\ x\ 10^{-3} = 0{,}86227$$

$$\tau_{tLx} = \frac{\tau_{tH}^{-1/e_{tH}}}{\pi} \tau_{tLi}^{-(1-e_{tL})/e_{tL}} + A(1 + \frac{1-e_{tL}}{e_{tL}} \frac{\tau_{tH}^{-1/e_{tH}}\ \tau_{tLi}^{-1/e_{tL}}}{\pi})^2$$

$$\tau_{tLx} = \frac{0{,}77469^{-1/0{,}89}}{1{,}55124} 0{,}86227^{-(1/0{,}91)/0{,}91} +$$

$$3{,}9\ x\ 10^{-3}(1 + \frac{1-0{,}91}{0{,}91} \frac{0{,}77469^{-1/0{,}89} x\ 0{,}86227^{-1/0{,}91}}{1{,}55124})^2$$

$$\tau_{tLx} = 0{,}875763$$

$$\tau_{tLxx} = \frac{\tau_{tH}^{-1/e_{tH}}}{\pi} \tau_{tLx}^{-(1-e_{tL})/e_{tL}} + A(1 + \frac{1-e_{tL}}{e_{tL}} \frac{\tau_{tH}^{-1/e_{tH}}\ \tau_{tLx}^{-1/e_{tL}}}{\pi})^2$$

$$\tau_{tLxx} = \frac{0{,}77469^{-1/0{,}89}}{1{,}55124} 0{,}875763^{-(1/0{,}91)/0{,}91} +$$

$$3{,}9\ x\ 10^{-3}(1 + \frac{1-0{,}91}{0{,}91} \frac{0{,}77469^{-1/0{,}89} x\ 0{,}875763^{-1/0{,}91}}{1{,}55124})^2$$

$$\tau_{tLxx} = 0{,}87441$$

$$\tau_{tLxxx} = \frac{\tau_{tH}^{-1/e_{tH}}}{\pi} \tau_{tLxx}^{-(1-e_{tL})/e_{tL}} + A(1 + \frac{1-e_{tL}}{e_{tL}} \frac{\tau_{tH}^{-1/e_{tH}}\ \tau_{tLxx}^{-1/e_{tL}}}{\pi})^2$$

$$\tau_{tLxxx} = \frac{0{,}77469^{-1/0{,}89}}{1{,}55124} 0{,}87441^{-(1/0{,}91)/0{,}91} +$$

$$3{,}9\ x\ 10^{-3}(1 + \frac{1-0{,}91}{0{,}91} \frac{0{,}77469^{-1/0{,}89} x\ 0{,}87441^{-1/0{,}91}}{1{,}55124})^2$$

$$\tau_{tLxxx} = 0{,}87455$$

$\tau_{tLxxx} - \tau_{tLxx} = 0{,}87455 - 0{,}87441 = 0{,}00014$ telah terpenuhi iterasi. Sehingga nilai *Turbine Low Temperature Ratio* (τ_{tLi}^{*}) sebesar 0,87455

15) Menghitung *Turbine Low Pressure Ratio*:

$$\pi_{tL} = \tau_{tL}^{\gamma\frac{t}{\gamma_t - 1 e_{tL}}}$$

$$\pi_{tL} = 0{,}87455^{\frac{1,3}{(1,3-1)0,91}} = 0{,}52817$$

16) Menghitung *Ratio Total Pressure dan Overall Pressure*:

$$\frac{P_{t9}}{P_0} = \pi_r \pi_d \pi_c \pi_b \pi_{tH} \pi_{tL} \pi_n$$

$$\frac{P_{t9}}{P_0} = 1{,}041 x\ 0{,}97\ x\ 7\ x\ 0{,}96\ x\ 0{,}28852\ x\ 0{,}52817 x\ 0{,}99$$

$$\frac{P_{t9}}{P_0} = 1{,}02371$$

17) Menghitung rasio kecepatan aliran udara di *nozzle* dan *Sound Speed*:

$$\frac{V_9}{a_0} = \sqrt{\frac{2\tau_\lambda \tau_{tH} \tau_{tL}}{\gamma_c - 1} [1 - \left(\frac{P_{t9}}{P_9}\right)^{-(\gamma_t - 1)/\gamma_t}]}$$

$dimana$:

$$\frac{P_{t9}}{P_9} = \left(\frac{\gamma_t + 1}{2}\right)^{\gamma_{t/(\gamma_t - 1)}}$$

Maka:

$$\frac{P_{t9}}{P_9} = \left(\frac{1{,}3 + 1}{2}\right)^{1,3/(1,3-1)} = 1{,}83242$$

$$\frac{P_0}{P_9} = \frac{\frac{P_{t9}}{P_9}}{\frac{P_{t9}}{P_0}} = \frac{1{,}83242}{1{,}02371} = 1{,}78998$$

Sehingga:

$$\frac{V_9}{a_0} = \sqrt{\frac{2\ x\ 3{,}82395\ x\ 0{,}77469\ x\ 0{,}87455}{1{,}4 - 1} [1 - (1{,}83242)^{-(1,3-1)/1,3}]}$$

$$\frac{V_9}{a_0} = 1{,}29985$$

18) Menghitung Koefisien Kerja *Output Propeller*:

$$C_{prop} = \eta_{prop}\eta_g\eta_{mL}(1+f)\tau_\lambda\tau_{tH}(1-\tau_{tL})$$

$$C_{prop} = 0{,}83x\ 0{,}99\ x\ 0{,}99(1+0{,}01367)\ 3{,}82395\ x\ 0{,}77469(1-0{,}87455)$$

$$C_{prop} = 0{,}30640$$

19) Menghitung Koefisien Kerja *Compressor Core:*

$$C_c = (\gamma_c - 1)M_0[(1+f)\frac{V_9}{a_0} - M_0 + (1+f)\frac{R_t}{R_c}\frac{\frac{T_9}{T_0}}{\frac{V_9}{a_0}} - \frac{1-\frac{P_0}{P_9}}{\gamma_c}$$

$dimana$:

$$\frac{T_9}{T_0} = \frac{\frac{T_{t9}}{T_0}}{\left(\frac{P_{t9}}{P_9}\right)^{(\gamma_t-1)/\gamma_t}}$$

dan

$$\frac{T_{t9}}{T_0} = \frac{T_{t4}}{T_0}\tau_{tH}\tau_{tL}$$

$$\frac{T_{t9}}{T_0} = \frac{1.724{,}67}{518{,}67}0{,}77469x\ 0{,}87455 = 2{,}2582$$

Maka:

$$\frac{T_9}{T_0} = \frac{2{,}2582}{(1{,}83242)^{(1{,}3-1)/1{,}3}} = 1{,}95897$$

Sehingga:

$$C_c = (1{,}4-1)0{,}240276(1+0{,}01367)1{,}29553 - 0{,}240276 + (1+0{,}01367)\frac{49{,}56281}{53{,}35954}\frac{1{,}95897}{1{,}29985} - \frac{1-1{,}78998}{1{,}4}$$

$$C_c = 0{,}02659$$

20) Menghitung koefisien kerja *output* pada *engine core total:*

$$C_{tot} = C_{prop} + C_c$$

$$C_{tot} = 0{,}30640 + 0{,}02659$$

$$C_{tot} = 0{,}33304$$

21) Menghitung *Thrust and Mass Flow Ratio*:

$$\frac{F}{\dot{m}_0} = \frac{C_{tot} C_{pc} T_0}{V_0}$$

$$\frac{F}{\dot{m}_0} = \frac{0{,}33304\ x\ 0{,}24\ x\ 518{,}67}{268{,}2736}$$

$$\frac{F}{\dot{m}_0} = 202{,}94439\ lbf/(lbm/sec)$$

22) Menghitung *Specific Fuel Consumption:*

$$S = \frac{f}{F/\dot{m}_0}$$

$$S = \frac{0{,}01367\ x\ 3600}{202{,}94439} = 0{,}24245\ (lbm/hr)/lbf$$

23) Menghitung *Specific Power*:

$$\frac{\dot{W}}{\dot{m}_0} = C_{tot} C_{pc} T_0$$

$$\frac{\dot{W}}{\dot{m}_0} = 0{,}33304 x\ 0{,}24\ x\ 518{,}67$$

$$\frac{\dot{W}}{\dot{m}_0} = 41{,}457771\ hp/(lbm/sec)$$

24) Menghitung *Efficiency Thermal*, *Propulsive*, *Overall*

$$\eta T = \frac{0{,}33304}{\frac{0{,}01367 x\ 18.400}{0{,}276 x 518{,}67}} = 16{,}5\%$$

$$\eta P = \frac{0{,}33304}{\left(\frac{0{,}30640}{0{,}83}\right) + \left(\frac{1{,}4-1}{2}\right) x\ (1 + 0{,}01367) x\ [(1{,}29985)^2 - 0{,}240276^2]}$$

$$\eta P = 47{,}6\%$$

$$\eta O = 16{,}5\%\ x\ 47{,}6\% = 7{,}9\%$$

14. Perhitungan *performance* setelah *TBO Extension* (5.600 *hours*) pada ketinggian 7.500 ft berdasarkan data *Aircraft Flight Log (AFL)*. Tabel 1.15 merupakan parameter *input engine TBO extension* 5.600 *hours*.

Tabel 1.15 Parameter *Input Engine TBO* 3600 *hours*

Parameter	*Input*	Satuan
T_0	518,67	^{0}R
Tt_4	1.733,67	^{0}R

Perhitungan:

1) Menghitung konstanta gas di kompresor:

$$R_c = \frac{\gamma_c - 1}{\gamma_c} C_{pc}$$

$$R_c = \frac{1,4 - 1}{1,4} 0,24$$

$$R_c = 0,06857\ BTU/lbm.°R$$

$$R_c = 0,06857\ x\ 778,16\ ft.lbf/lbm.°R$$

$$R_c = 53,35954\ ft.lbf/lbm.°R$$

2) Menghitung konstanta gas di t*urbine*:

$$R_t = \frac{\gamma_t - 1}{\gamma_t} C_{pt}$$

$$R_t = \frac{1,3-1}{1,3} 0,276 = 0,63692\ BTU/lbm.°R$$

$$R_t = 0,63692\ x\ 778,16\ ft.lbf/bm.°R$$

$$R_t = 49,56281\ ft.lbf/bm.°R$$

3) Menghitung *Sound Speed* atau kecepatan suara:

$$a_0 = \sqrt{\gamma_c\ R_c\ g_c\ T_0}$$

$$a_0 = \sqrt{1,4\ \text{x}\ 53,35954\ x\ 32,174\ x\ 518,67}$$

$$a_0 = 1.116,524425\ ft/sec$$

4) Menghitung *Absolute velocity*:

V_0= TAS=$(\frac{FL}{1.000} x\ 2\%\ x\ 0{,}98\ x\ IAS) + IAS$

V_0= $(\frac{7500}{1000} x\ 2\%\ x\ 0{,}98\ x\ 138) + 138$

V_0= $158{,}286 knot$

V_0= $158{,}286 NM/hr$

V_0= $158{,}286 x\ 1{,}852\ km/hr$

V_0= $293{,}146\ km/hr$

V_0= $81{,}425\ m/sec$

V_0= $81{,}425 x\ 3{,}2808 = 267{,}1303\ ft/sec$

5) Menghitung *Ratio Temperature Ram*:

$$\tau_r = 1 + \frac{\gamma_c - 1}{2} M_0^2$$

dimana:

$M_0 = V_0/a_0$

$M_0 = \frac{267{,}1303}{1.116{,}524425} = 0{,}239252 Mach$

$$\tau_r = 1 + \frac{1{,}4 - 1}{2} 0{,}239252^2$$

$\tau_r = 1{,}01145$

6) Menghitung *Ram Pressure Ratio*:

$\pi_r = \tau_r^{\gamma_c/\ (\gamma_c - 1)}$

$\pi_r = 1{,}01145^{1{,}4/\ (1{,}4-1)} = 1{,}04065$

7) Menghitung *Inlet Pressure Ratio:*

$\pi_d = \pi_{dmax}\ x\ \eta_r$

Dimana:

η_r= 1 untuk $M_0 \leq 1$

$\eta_r = 1 - 0{,}0075(M_0 - 1)^{1{,}35}$ untuk $M_0 \geq 1$

$$\pi_d = 0{,}97\ x\ 1 = 0{,}97$$

8) Menghitung *entalphy ratio* di ruang bakar dengan *ambient temperature* pada ketinggian terbang:

$$\tau_\lambda = \frac{C_{pt}\ x\ T_{t4}}{C_{pc}T_0}$$

$$\tau_\lambda = \frac{0{,}276\ x 1.733{,}67}{0{,}24\ x\ 518{,}67} = 3{,}84391$$

9) Menghitung *temperature ratio* di ruang bakar dengan *ambient temperature* pada ketinggian terbang :

$$\tau_c = \pi_c{}^{(\gamma_c - 1)/\ (\gamma_c\ \varepsilon_c)}$$

$$\tau_c = 7^{(1{,}4-1)/\ (1{,}4\ x\ 0{,}90)} = 1{,}85475$$

10) Menghitung *Compressor Efficiency*:

$$\eta_c = \frac{\pi_c{}^{(\gamma_c - 1)/\gamma_c} - 1}{\tau_c - 1}$$

$$\eta_c = \frac{7^{(1{,}4-1)/1{,}4} - 1}{1{,}85475 - 1} = 0{,}87001$$

11) Menghitung *Fuel/Air Ratio:*

$$f = \frac{\tau_\lambda - \tau_r\tau_c}{\eta_b h_{PR}/(C_{pc}T_0) - \tau_\lambda}$$

$$f = \frac{3{,}84391 - 1{,}01145\ x\ 1{,}85475}{0{,}99\ x\ 18.400/(0{,}24\ x\ 518{,}67) - 3{,}84391} = 0{,}01381$$

12) Menghitung *High Temperature Turbine*:

$$\tau_{tH} = 1 - \frac{\tau_r(\tau_c - 1)}{\eta_{mH}(1+f)\tau_\lambda}$$

$$\tau_{tH} = 1 - \frac{1{,}01145\ (1{,}85475 - 1)}{0{,}99(1 + 0{,}01381)3{,}84391} = 0{,}77591$$

13) Menghitung *Turbine High Temperature Ratio*:

$$\pi_{tH} = \tau_{tH}^{\gamma_t/[(\gamma_t-1)e_{tH}]}$$

$$\pi_{tH} = 0,77591^{\frac{1,3}{(1,3-1)0,89}} = 0,29074$$

14) Menghitung *Turbine Low Temperature Ratio*:

$$\tau_{tLi}^{*} = \frac{\tau_{tH}^{-1/e_{tH}}}{\pi} + A$$

Dimana

$$\pi = (\pi_r \pi_d \pi_c \pi_b \pi_n)^{(\gamma_t-1)/\gamma_t}$$

dan

$$A = \frac{\left[\frac{\gamma_c - 1}{2}\right]\left[\frac{M_0^2}{(\tau_\lambda \tau_{tH})}\right]}{(\eta_{prop}\eta_g\eta_{mL})^2}$$

$maka$:

$$\pi = (1,04065\ x\ 0,97\ x\ 7\ x\ 0,96\ x\ 0,99)^{(1,3-1)/\,1,3} = 1,5519$$

dan

$$A = \frac{\left[\frac{1,4 - 1}{2}\right]\left[\frac{0,239252^2}{(3,84391\ x\ 0,77591)}\right]}{(0,83x\ 0,99\ x\ 0,99)^2} = 3,84x\ 10^{-3}$$

Selanjutnya nilai τ_{tLi}^{*} dilakukan iterasi sampai nilainya mendekati 0,0001.

$$\tau_{tLi}^{*} = \frac{0,77591^{-1/0,89}}{1,5519} + 3,84x\ 10^{-3} = 0,86076$$

$$\tau_{tLx} = \frac{\tau_{tH}^{-1/e_{tH}}}{\pi}\tau_{tLi}^{-(1-e_{tL})/e_{tL}} + A(1 + \frac{1-e_{tL}}{e_{tL}}\frac{\tau_{tH}^{-1/e_{tH}}\ \tau_{tLi}^{-1/e_{tL}}}{\pi})^2$$

$$\tau_{tLx} = \frac{0,77591^{-1/0,89}}{1,5519}0,86076^{-(1/0,91)/0,91} +$$

$$3,84x\ 10^{-3}(1 + \frac{1-0,91}{0,91}\frac{0,77591^{-1/0,89}x\ 0,86076^{-1/0,91}}{1,5519})^2$$

$$\tau_{tLx} = 0,874368$$

$$\tau_{tLxx} = \frac{\tau_{tH}^{-1/e_{tH}}}{\pi} \tau_{tLx}^{-(1-e_{tL})/e_{tL}} + A(1 + \frac{1-e_{tL}}{e_{tL}} \frac{\tau_{tH}^{-1/e_{tH}}\ \tau_{tLx}^{-1/e_{tL}}}{\pi})^2$$

$$\tau_{tLxx} = \frac{0{,}77591^{-1/0{,}89}}{1{,}5519} 0{,}874368^{-(1/0{,}91)/0{,}91} +$$

$$3{,}84x\ 10^{-3}(1 + \frac{1-0{,}91}{0{,}91} \frac{0{,}77591^{-1/0{,}89} x\ 0{,}874368^{-1/0{,}91}}{1{,}5519})^2$$

$$\tau_{tLxx} = 0{,}87301$$

$$\tau_{tLxxx} = \frac{\tau_{tH}^{-1/e_{tH}}}{\pi} \tau_{tLxx}^{-(1-e_{tL})/e_{tL}} + A(1 + \frac{1-e_{tL}}{e_{tL}} \frac{\tau_{tH}^{-1/e_{tH}}\ \tau_{tLxx}^{-1/e_{tL}}}{\pi})^2$$

$$\tau_{tLxxx} = \frac{0{,}77591^{-1/0{,}89}}{1{,}5519} 0{,}87301^{-(1/0{,}91)/0{,}91} +$$

$$3{,}84x\ 10^{-3}(1 + \frac{1-0{,}91}{0{,}91} \frac{0{,}77591^{-1/0{,}89} x\ 0{,}87301^{-1/0{,}91}}{1{,}5519})^2$$

$$\tau_{tLxxx} = 0{,}87314$$

$\tau_{tLxxx} - \tau_{tLxx} = 0{,}87314 - 0{,}87301 = 0{,}00013$ telah terpenuhi iterasi.

Sehingga nilai *Turbine Low Temperature Ratio* (τ_{tLi}^*) sebesar 0,87314

15) Menghitung *Turbine Low Pressure Ratio*:

$$\pi_{tL} = \tau_{tL}^{\frac{\gamma_t}{\gamma_t - 1 e_{tL}}}$$

$$\pi_{tL} = 0{,}87314^{\frac{1{,}3}{(1{,}3-1)0{,}91}} = 0{,}52414$$

16) Menghitung *Ratio Total Pressure dan Overall Pressure*:

$$\frac{P_{t9}}{P_0} = \pi_r \pi_d \pi_c \pi_b \pi_{tH} \pi_{tL} \pi_n$$

$$\frac{P_{t9}}{P_0} = 1{,}04065x\ 0{,}97\ x\ 7\ x\ 0{,}96\ x\ 0{,}29074\ x\ 0{,}52414x\ 0{,}99$$

$$\frac{P_{t9}}{P_0} = 1{,}02338$$

17) Menghitung rasio kecepatan aliran udara di *nozzle* dan *Sound Speed*:

$$\frac{V_9}{a_0} = \sqrt{\frac{2\tau_\lambda \tau_{tH} \tau_{tL}}{\gamma_c - 1} [1 - \left(\frac{P_{t9}}{P_9}\right)^{-(\gamma_t - 1)/\gamma_t}]}$$

$dimana$:

$$\frac{P_{t9}}{P_9} = \left(\frac{\gamma_t + 1}{2}\right)^{\gamma_{t/(\gamma_t - 1)}}$$

Maka:

$$\frac{P_{t9}}{P_9} = \left(\frac{1,3 + 1}{2}\right)^{1,3/(1,3-1)} = 1,83242$$

$$\frac{P_0}{P_9} = \frac{\frac{P_{t9}}{P_9}}{\frac{P_{t9}}{P_0}} = \frac{1,83242}{1,02338} = 1,79055$$

Sehingga:

$$\frac{V_9}{a_0} = \sqrt{\frac{2\ x\ 3,84391\ x\ 0,77591\ x\ 0,87314}{1,4 - 1} [1 - (1,83242)^{-(1,3-1)/1,3}]}$$

$$\frac{V_9}{a_0} = 1,30322$$

18) Menghitung Koefisien Kerja *Output Propeller*:

$$C_{prop} = \eta_{prop} \eta_g \eta_{mL} (1 + f) \tau_\lambda \tau_{tH} (1 - \tau_{tL})$$

$$C_{prop} = 0,83x\ 0,99\ x\ 0,99(1 + 0,01381)\ 3,84391\ x\ 0,77591(1 - 0,87314)$$

$$C_{prop} = 0,31204$$

19) Menghitung Koefisien Kerja *Compressor Core:*

$$C_c = (\gamma_c - 1)M_0 [(1 + f) \frac{V_9}{a_0} - M_0 + (1 + f) \frac{R_t}{R_c} \frac{\frac{T_9}{T_0}}{\frac{V_9}{a_0}} - \frac{1 - \frac{P_0}{P_9}}{\gamma_c}$$

$dimana$:

$$\frac{T_9}{T_0} = \frac{\frac{T_{t9}}{T_0}}{\left(\frac{P_{t9}}{P_9}\right)^{(\gamma_t - 1)/\gamma_t}}$$

dan

$$\frac{T_{t9}}{T_0} = \frac{T_{t4}}{T_0} \tau_{tH} \tau_{tL}$$

$$\frac{T_{t9}}{T_0} = \frac{1.733,67}{518,67} 0,77591 x\ 0,87314 = 2,2645$$

Maka:

$$\frac{T_9}{T_0} = \frac{2,2645}{(1,83242)^{(1,3-1)/_{1,3}}} = 1,96913$$

Sehingga:

$$C_c = (1,4-1)0,239252(1+0,01381)1,30322 - 0,239252 + (1+0,01381)\frac{49,56281}{53,35954}\frac{1,96913}{1,30322} - \frac{1-1,79055}{1,4}$$

$$C_c = 0,02665$$

20) Menghitung koefisien kerja *output* pada *engine core total:*

$$C_{tot} = C_{prop} + C_c$$

$$C_{tot} = 0,31204 + 0,02665$$

$$C_{tot} = 0,3387$$

21) Menghitung *Thrust and Mass Flow Ratio*:

$$\frac{F}{\dot{m}_0} = \frac{C_{tot} C_{pc} T_0}{V_0}$$

$$\frac{F}{\dot{m}_0} = \frac{0,3387\ x\ 0,24\ x\ 518,67}{267,1303}$$

$$\frac{F}{\dot{m}_0} = 207,27105\ lbf/(lbm/sec)$$

22) Menghitung *Specific Fuel Consumption:*

$$S = \frac{f}{F/_{\dot{m}_0}}$$

$$S = \frac{0,01381\ x\ 3600}{207,27105} = 0,23987\ (lbm/hr)/lbf$$

23) Menghitung *Specific Power*:

$$\frac{\dot{W}}{\dot{m}_0} = C_{tot}C_{pc}T_0$$

$$\frac{\dot{W}}{\dot{m}_0} = 0{,}3387x\ 0{,}24\ x\ 518{,}67$$

$$\frac{\dot{W}}{\dot{m}_0} = 42{,}16113\ hp/(lbm/sec)$$

24) Menghitung *Efficiency Thermal*, *Propulsive*, *Overall*

$$\eta T = \frac{0{,}3387}{\frac{0{,}01381x\ 18.400}{0{,}276x518{,}67}} = 16{,}6\%$$

$$\eta P = \frac{0{,}3387}{\left(\frac{0{,}31204}{0{,}83}\right) + \left(\frac{1{,}4-1}{2}\right) x\ (1+0{,}01381) x\ [(1{,}30322)^2 - 0{,}239252^2]}$$

$$\eta P = 47{,}8\%$$

$$\eta O = 16{,}6\%\ x\ 47{,}8\% = 7{,}9\%$$

15. Perhitungan *performance* setelah *TBO Extension* (5.600 *hours*) pada ketinggian 8.500 ft berdasarkan data *Aircraft Flight Log (AFL)*. Tabel 1.16 merupakan parameter *input engine TBO extension* 5.600 *hours*.

Tabel 1.16 Parameter *Input Engine TBO* 3600 *hours*

Parameter	*Input*	Satuan
T_0	516,87	^{0}R
Tt_4	1.742,67	^{0}R

Perhitungan:

1) Menghitung konstanta gas di kompresor:

$$R_c = \frac{\gamma_c - 1}{\gamma_c} C_{pc}$$

$$R_c = \frac{1{,}4 - 1}{1{,}4} 0{,}24$$

$$R_c = \ 0{,}06857\ BTU/lbm.°R$$

$$R_c = \ 0{,}06857\ x\ 778{,}16\ ft.lbf/lbm.°R$$

$$R_c = \ 53{,}35954\ ft.lbf/lbm.°R$$

2) Menghitung konstanta gas di t*urbine*:

$$R_t = \frac{\gamma_t - 1}{\gamma_t} C_{pt}$$

$$R_t = \frac{1{,}3-1}{1{,}3} 0{,}276\ = 0{,}63692\ BTU/lbm.°R$$

$$R_t = 0{,}63692\ x\ 778{,}16\ \ ft.lbf/bm.°R$$

$$R_t = 49{,}56281\ \ ft.lbf/bm.°R$$

3) Menghitung *Sound Speed* atau kecepatan suara:

$$a_0 = \sqrt{\gamma_c\ R_c\ \ g_c\ T_0}$$

$$a_0 = \sqrt{1{,}4\ \text{x}\ \ 53{,}35954\ x\ 32{,}174\ x\ 516{,}87}$$

$$a_0 = 1.114{,}58517 ft/sec$$

4) Menghitung *Absolute velocity*:

V_0= TAS=$(\frac{FL}{1.000} x\ 2\%\ x\ 0{,}98\ x\ IAS) + IAS$

V_0= $(\frac{8500}{1000} x\ 2\%\ x\ 0{,}98\ x\ 135) + 135$

V_0= $157{,}491 knot$

V_0= $157{,}491 NM/hr$

V_0= $157{,}491 x\ 1{,}852\ km/hr$

V_0= $291{,}673\ km/hr$

V_0= $81{,}02\ m/sec$

V_0= $\ 81{,}02 x\ 3{,}2808 = 265{,}7887\ ft/sec$

5) Menghitung $Ratio\ Temperature\ Ram$:

$$\tau_r = 1 + \frac{\gamma_c - 1}{2} M_0^2$$

$dimana$:

$$M_0 = V_0/a_0$$

$$M_0 = \frac{265{,}7887}{1.114{,}58517} = 0{,}238464 Mach$$

$$\tau_r = 1 + \frac{1{,}4 - 1}{2} 0{,}238464^2$$

$$\tau_r = 1{,}01137$$

6) Menghitung $Ram\ Pressure\ Ratio$:

$$\pi_r = {\tau_r}^{\gamma_c/\,(\gamma_c - 1)}$$

$$\pi_r = 1{,}01137^{1{,}4/\,(1{,}4-1)} = 1{,}04037$$

7) Menghitung *Inlet Pressure Ratio:*

$$\pi_d = \pi_{dmax}\ x\ \eta_r$$

Dimana:

η_r= 1 untuk $M_0 \leq 1$

$\eta_r = 1 - 0{,}0075(M_0 - 1)^{1{,}35}$ untuk $M_0 \geq 1$

$$\pi_d = 0{,}97\ x\ 1 = 0{,}97$$

8) Menghitung *entalphy ratio* di ruang bakar dengan *ambient temperature* pada ketinggian terbang:

$$\tau_\lambda = \frac{C_{pt}\ x\ T_{t4}}{C_{pc} T_0}$$

$$\tau_\lambda = \frac{0{,}276\ x 1.742{,}67}{0{,}24\ x\ 516{,}87} = 3{,}87732$$

9) Menghitung *temperature ratio* di ruang bakar dengan *ambient temperature* pada ketinggian terbang :

$$\tau_c = {\pi_c}^{(\gamma_c - 1)/\,(\gamma_c\ \varepsilon_c)}$$

$$\tau_c = 7^{(1{,}4-1)/\,(1{,}4\ x\ 0{,}90)} = 1{,}85475$$

10) Menghitung *Compressor Efficiency*:

$$\eta_c = \frac{\pi_c{}^{(\gamma_c - 1)/\gamma_c} - 1}{\tau_c - 1}$$

$$\eta_c = \frac{7^{(1,4-1)/1,4} - 1}{1,85475 - 1} = 0,87001$$

11) Menghitung *Fuel/Air Ratio:*

$$f = \frac{\tau_\lambda - \tau_r \tau_c}{\eta_b h_{PR}/(C_{pc}T_0) - \tau_\lambda}$$

$$f = \frac{3,87732 - 1,01137\ x\ 1,85475}{0,99\ x\ 18.400/(0,24\ x\ 516,87) - 3,87732} = 0,014$$

12) Menghitung *High Temperature Turbine*:

$$\tau_{tH} = 1 - \frac{\tau_r(\tau_c - 1)}{\eta_{mH}(1 + f)\tau_\lambda}$$

$$\tau_{tH} = 1 - \frac{1,01137\ (1,85475 - 1)}{0,99(1 + 0,014)3,87732} = 0,7779$$

13) Menghitung *Turbine High Temperature Ratio*:

$$\pi_{tH} = \tau_{tH}^{\gamma_t/[(\gamma_t - 1)e_{tH}]}$$

$$\pi_{tH} = 0,7779^{\frac{1,3}{(1,3-1)0,89}} = 0,29439$$

14) Menghitung *Turbine Low Temperature Ratio*:

$$\tau_{tLi}^* = \frac{\tau_{tH}^{-1/e_{tH}}}{\pi} + A$$

Dimana

$$\pi = (\pi_r \pi_d \pi_c \pi_b \pi_n)^{(\gamma_t - 1)/\ \gamma_t}$$

dan

$$A = \frac{\left[\frac{\gamma_c - 1}{2}\right]\left[\frac{M_0^2}{(\tau_\lambda\ \tau_{tH})}\right]}{(\eta_{prop}\eta_g\eta_{mL})^2}$$

$maka$:

$$\pi = (1{,}04037\ x\ 0{,}97\ x\ 7\ x\ 0{,}96\ x\ 0{,}99)^{(1{,}3-1)/\ 1{,}3} = 1{,}55181$$

dan

$$A = \frac{\left[\frac{1{,}4-1}{2}\right]\left[\frac{0{,}238464^2}{(3{,}87732\ x\ 0{,}7779)}\right]}{(0{,}83x\ 0{,}99\ x\ 0{,}99)^2} = 3{,}77x\ 10^{-3}$$

Selanjutnya nilai τ^*_{tLi} dilakukan iterasi sampai nilainya mendekati 0,0001.

$$\tau^*_{tLi} = \frac{0{,}7779^{-1/0{,}89}}{1{,}55181} + 3{,}77x\ 10^{-3} = 0{,}85828$$

$$\tau_{tLx} = \frac{\tau_{tH}^{-1/e_{tH}}}{\pi}\tau_{tLi}^{-(1-e_{tL})/e_{tL}} + A(1 + \frac{1-e_{tL}}{e_{tL}}\frac{\tau_{tH}^{-1/e_{tH}}\ \tau_{tLi}^{-1/e_{tL}}}{\pi})^2$$

$$\tau_{tLx} = \frac{0{,}7779^{-1/0{,}89}}{1{,}55181}0{,}85828^{-(1/0{,}91)/0{,}91} +$$

$$3{,}77x\ 10^{-3}(1 + \frac{1-0{,}91}{0{,}91}\frac{0{,}7779^{-1/0{,}89}x\ 0{,}85828^{-1/0{,}91}}{1{,}55181})^2$$

$$\tau_{tLx} = 0{,}872088$$

$$\tau_{tLxx} = \frac{\tau_{tH}^{-1/e_{tH}}}{\pi}\tau_{tLx}^{-(1-e_{tL})/e_{tL}} + A(1 + \frac{1-e_{tL}}{e_{tL}}\frac{\tau_{tH}^{-1/e_{tH}}\ \tau_{tLx}^{-1/e_{tL}}}{\pi})^2$$

$$\tau_{tLxx} = \frac{0{,}7779^{-1/0{,}89}}{1{,}55181}0{,}872088^{-(1/0{,}91)/0{,}91} +$$

$$3{,}77x\ 10^{-3}(1 + \frac{1-0{,}91}{0{,}91}\frac{0{,}7779^{-1/0{,}89}x\ 0{,}872088^{-1/0{,}91}}{1{,}55181})^2$$

$$\tau_{tLxx} = 0{,}87071$$

$$\tau_{tLxxx} = \frac{\tau_{tH}^{-1/e_{tH}}}{\pi}\tau_{tLxx}^{-(1-e_{tL})/e_{tL}} + A(1 + \frac{1-e_{tL}}{e_{tL}}\frac{\tau_{tH}^{-1/e_{tH}}\ \tau_{tLxx}^{-1/e_{tL}}}{\pi})^2$$

$$\tau_{tLxxx} = \frac{0{,}7779^{-1/0{,}89}}{1{,}55181}0{,}87071^{-(1/0{,}91)/0{,}91} +$$

$$3{,}77x\ 10^{-3}(1 + \frac{1-0{,}91}{0{,}91}\frac{0{,}7779^{-1/0{,}89}x\ 0{,}87071^{-1/0{,}91}}{1{,}55181})^2$$

$$\tau_{tLxxx} = 0{,}87084$$

$\tau_{tLxxx} - \tau_{tLxx} = 0{,}87084 - 0{,}87071 = 0{,}00013$ telah terpenuhi iterasi. Sehingga nilai *Turbine Low Temperature Ratio* (τ^*_{tLi}) sebesar 0,87084

15) Menghitung *Turbine Low Pressure Ratio*:

$$\pi_{tL} = \tau_{tL}^{\frac{\gamma_t}{\gamma_t - 1 e_{tL}}}$$

$$\pi_{tL} = 0{,}87084^{\frac{1{,}3}{(1{,}3-1)0{,}91}} = 0{,}51761$$

16) Menghitung *Ratio Total Pressure dan Overall Pressure*:

$$\frac{P_{t9}}{P_0} = \pi_r \pi_d \pi_c \pi_b \pi_{tH} \pi_{tL} \pi_n$$

$$\frac{P_{t9}}{P_0} = 1{,}04037 x\ 0{,}97\ x\ 7\ x\ 0{,}96\ x\ 0{,}29439\ x\ 0{,}51761 x\ 0{,}99$$

$$\frac{P_{t9}}{P_0} = 1{,}023$$

17) Menghitung rasio kecepatan aliran udara di *nozzle* dan *Sound Speed*:

$$\frac{V_9}{a_0} = \sqrt{\frac{2\tau_\lambda \tau_{tH} \tau_{tL}}{\gamma_c - 1}[1 - \left(\frac{P_{t9}}{P_9}\right)^{-(\gamma_t - 1)/\gamma_t}]}$$

dimana:

$$\frac{P_{t9}}{P_9} = \left(\frac{\gamma_t + 1}{2}\right)^{\gamma_{t/(\gamma_t - 1)}}$$

Maka:

$$\frac{P_{t9}}{P_9} = \left(\frac{1{,}3 + 1}{2}\right)^{1{,}3/(1{,}3-1)} = 1{,}83242$$

$$\frac{P_0}{P_9} = \frac{\frac{P_{t9}}{P_9}}{\frac{P_{t9}}{P_0}} = \frac{1{,}83242}{1{,}023} = 1{,}79117$$

Sehingga:

$$\frac{V_9}{a_0} = \sqrt{\frac{2\ x\ 3{,}87732\ x\ 0{,}7779\ x\ 0{,}87084}{1{,}4 - 1}[1 - (1{,}83242)^{-(1{,}3-1)/1{,}3}]}$$

$$\frac{V_9}{a_0} = 1{,}30882$$

18) Menghitung Koefisien Kerja *Output Propeller*:

$$C_{prop} = \eta_{prop}\eta_g\eta_{mL}(1+f)\tau_\lambda\tau_{tH}(1-\tau_{tL})$$

$$C_{prop} = 0{,}83x\ 0{,}99\ x\ 0{,}99(1+0{,}014)\ 3{,}87732\ x\ 0{,}7779(1-0{,}87084)$$

$$C_{prop} = 0{,}32134$$

19) Menghitung Koefisien Kerja *Compressor Core:*

$$C_c = (\gamma_c - 1)M_0[(1+f)\frac{V_9}{a_0} - M_0 + (1+f)\frac{R_t}{R_c}\frac{\frac{T_9}{T_0}}{\frac{V_9}{a_0}} - \frac{1-\frac{P_0}{P_9}}{\gamma_c}$$

dimana:

$$\frac{T_9}{T_0} = \frac{\frac{T_{t9}}{T_0}}{\left(\frac{P_{t9}}{P_9}\right)^{(\gamma_t-1)/\gamma_t}}$$

dan

$$\frac{T_{t9}}{T_0} = \frac{T_{t4}}{T_0}\tau_{tH}\tau_{tL}$$

$$\frac{T_{t9}}{T_0} = \frac{1.742{,}67}{516{,}87}0{,}7779x\ 0{,}87084 = 2{,}28401$$

Maka:

$$\frac{T_9}{T_0} = \frac{2{,}28401}{(1{,}83242)^{(1{,}3-1)/1{,}3}} = 1{,}9861$$

Sehingga:

$$C_c = (1{,}4-1)0{,}238464(1+0{,}014)1{,}30882 - 0{,}238464 + (1+0{,}014)\frac{49{,}56281}{53{,}35954}\frac{1{,}9861}{1{,}30882} - \frac{1-1{,}79117}{1{,}4}$$

$$C_c = 0{,}0268$$

20) Menghitung koefisien kerja *output* pada *engine core total:*

$$C_{tot} = C_{prop} + C_c$$
$$C_{tot} = 0{,}32134 + 0{,}0268$$
$$C_{tot} = 0{,}34814$$

21) Menghitung *Thrust and Mass Flow Ratio*:

$$\frac{F}{\dot{m}_0} = \frac{C_{tot}C_{pc}T_0}{V_0}$$
$$\frac{F}{\dot{m}_0} = \frac{0{,}34814\ x\ 0{,}24\ x\ 516{,}87}{265{,}7887}$$
$$\frac{F}{\dot{m}_0} = 213{,}381\ lbf/(lbm/sec)$$

22) Menghitung *Specific Fuel Consumption:*

$$S = \frac{f}{F/\dot{m}_0}$$
$$S = \frac{0{,}014\ x\ 3600}{213{,}381} = 0{,}23619\ (lbm/hr)/lbf$$

23) Menghitung *Specific Power*:

$$\frac{\dot{W}}{\dot{m}_0} = C_{tot}C_{pc}T_0$$
$$\frac{\dot{W}}{\dot{m}_0} = 0{,}34814\ x\ 0{,}24\ x\ 516{,}87$$
$$\frac{\dot{W}}{\dot{m}_0} = 43{,}18632\ hp/(lbm/sec)$$

24) Menghitung *Efficiency Thermal*, *Propulsive*, *Overall*

$$\eta T = \frac{0{,}34814}{\frac{0{,}014x\ 18.400}{0{,}276x\ 516{,}87}} = 16{,}8\%$$

$$\eta P = \frac{0{,}34814}{\left(\frac{0{,}32134}{0{,}83}\right) + \left(\frac{1{,}4-1}{2}\right) x\ (1+0{,}014)x\ [(1{,}30882)^2 - 0{,}238464^2]}$$

$\eta P = 48{,}1\%$

$\eta O = 16{,}8\% \; x \; 48{,}1\% = 8{,}1\%$

16. Perhitungan *performance* setelah *TBO Extension* (5.600 *hours*) pada ketinggian 9.500 ft berdasarkan data *Aircraft Flight Log (AFL)*. Tabel 1.17 merupakan parameter *input engine TBO extension* 5.600 *hours*.

Tabel 1.17 Parameter *Input Engine TBO* 3600 *hours*

Parameter	*Input*	Satuan
T_0	515,07	^0R
Tt_4	1.744,67	^0R

Perhitungan:

1) Menghitung konstanta gas di kompresor:

$$R_c = \frac{\gamma_c - 1}{\gamma_c} C_{pc}$$

$$R_c = \frac{1{,}4 - 1}{1{,}4} 0{,}24$$

$$R_c = 0{,}06857 \; BTU/lbm.°R$$

$$R_c = 0{,}06857 \; x \; 778{,}16 \; ft.lbf/lbm.°R$$

$$R_c = 53{,}35954 \; ft.lbf/lbm.°R$$

2) Menghitung konstanta gas di t*urbine*:

$$R_t = \frac{\gamma_t - 1}{\gamma_t} C_{pt}$$

$$R_t = \frac{1{,}3-1}{1{,}3} 0{,}276 = 0{,}63692 \; BTU/lbm.°R$$

$$R_t = 0{,}63692 \; x \; 778{,}16 \; ft.lbf/bm.°R$$

$$R_t = 49{,}56281 \; ft.lbf/bm.°R$$

3) Menghitung *Sound Speed* atau kecepatan suara:

$$a_0 = \sqrt{\gamma_c \, R_c \, g_c \, T_0}$$

$a_0 = \sqrt{1{,}4 \text{ x } 53{,}35954\ x\ 32{,}174\ x\ 515{,}07}$

$a_0 = 1.112{,}6427 ft/sec$

4) Menghitung *Absolute velocity*:

V_0= TAS=$(\frac{FL}{1.000} x\ 2\%\ x\ 0{,}98\ x\ IAS) + IAS$

V_0= $(\frac{9500}{1000} x\ 2\%\ x\ 0{,}98\ x\ 132) + 132$

V_0= $156{,}578 knot$

V_0= $156{,}578 NM/hr$

V_0= $156{,}578 x\ 1{,}852\ km/hr$

V_0= $289{,}982\ km/hr$

V_0= $80{,}551\ m/sec$

V_0= $80{,}551 x\ 3{,}2808 = 264{,}2485\ ft/sec$

5) Menghitung $Ratio\ Temperature\ Ram$:

$$\tau_r = 1 + \frac{\gamma_c - 1}{2} M_0^2$$

$dimana$:

$M_0 = V_0/a_0$

$M_0 = \frac{264{,}2485}{1.112{,}6427} = 0{,}237496 Mach$

$$\tau_r = 1 + \frac{1{,}4 - 1}{2} 0{,}237496^2$$

$\tau_r = 1{,}01128$

6) Menghitung $Ram\ Pressure\ Ratio$:

$\pi_r = {\tau_r}^{\gamma_c/\ (\gamma_c - 1)}$

$\pi_r = 1{,}01128^{1{,}4/\ (1{,}4-1)} = 1{,}04004$

7) Menghitung *Inlet Pressure Ratio:*

$\pi_d = \pi_{dmax}\ x\ \eta_r$

Dimana:

η_r= 1 untuk $M_0 \leq 1$

$\eta_r = 1 - 0{,}0075(M_0 - 1)^{1,35}$ untuk $M_0 \geq 1$

$\pi_d = 0{,}97\ x\ 1 = 0{,}97$

8) Menghitung *entalphy ratio* di ruang bakar dengan *ambient temperature* pada ketinggian terbang:

$$\tau_\lambda = \frac{C_{pt}\ x\ T_{t4}}{C_{pc}T_0}$$

$$\tau_\lambda = \frac{0{,}276\ x 1.744{,}67}{0{,}24\ x\ 515{,}07} = 3{,}89534$$

9) Menghitung *temperature ratio* di ruang bakar dengan *ambient temperature* pada ketinggian terbang :

$$\tau_c = \pi_c{}^{(\gamma_c - 1)/\ (\gamma_c\ \varepsilon_c)}$$

$$\tau_c = 7^{(1,4-1)/\ (1,4\ x\ 0,90)} = 1{,}85475$$

10) Menghitung *Compressor Efficiency*:

$$\eta_c = \frac{\pi_c{}^{(\gamma_c - 1)/\gamma_c} - 1}{\tau_c - 1}$$

$$\eta_c = \frac{7^{(1,4-1)/1,4} - 1}{1{,}85475 - 1} = 0{,}87001$$

11) Menghitung *Fuel/Air Ratio:*

$$f = \frac{\tau_\lambda - \tau_r\tau_c}{\eta_b h_{PR}/(C_{pc}T_0) - \tau_\lambda}$$

$$f = \frac{3{,}89534 - 1{,}01128\ x\ 1{,}85475}{0{,}99\ x\ 18.400/(0{,}24\ x\ 515{,}07) - 3{,}89534} = 0{,}01408$$

12) Menghitung *High Temperature Turbine*:

$$\tau_{tH} = 1 - \frac{\tau_r(\tau_c - 1)}{\eta_{mH}(1 + f)\tau_\lambda}$$

$$\tau_{tH} = 1 - \frac{1{,}01128\,(1{,}85475 - 1)}{0{,}99(1 + 0{,}01408)3{,}89534} = 0{,}77897$$

13) Menghitung *Turbine High Temperature Ratio*:

$$\pi_{tH} = \tau_{tH}^{\gamma_t/[(\gamma_t - 1)e_{tH}]}$$

$$\pi_{tH} = 0{,}77897^{\frac{1{,}3}{(1{,}3-1)0{,}89}} = 0{,}29636$$

14) Menghitung *Turbine Low Temperature Ratio*:

$$\tau_{tLi}^{*} = \frac{\tau_{tH}^{-1/e_{tH}}}{\pi} + A$$

Dimana

$$\pi = (\pi_r \pi_d \pi_c \pi_b \pi_n)^{(\gamma_t - 1)/\,\gamma_t}$$

dan

$$A = \frac{\left[\frac{\gamma_c - 1}{2}\right]\left[\frac{M_0^2}{(\tau_\lambda\,\tau_{tH})}\right]}{(\eta_{prop}\eta_g\eta_{mL})^2}$$

$maka$:

$$\pi = (1{,}04004\ x\ 0{,}97\ x\ 7\ x\ 0{,}96\ x\ 0{,}99)^{(1{,}3-1)/\,1{,}3} = 1{,}55169$$

dan

$$A = \frac{\left[\frac{1{,}4 - 1}{2}\right]\left[\frac{0{,}237496^2}{(3{,}89534\ x\ 0{,}77897)}\right]}{(0{,}83x\ 0{,}99\ x\ 0{,}99)^2} = 3{,}72x\ 10^{-3}$$

Selanjutnya nilai τ_{tLi}^{*} dilakukan iterasi sampai nilainya mendekati 0,0001.

$$\tau_{tLi}^{*} = \frac{0{,}77897^{-1/0{,}89}}{1{,}55169} + 3{,}72x\ 10^{-3} = 0{,}85698$$

$$\tau_{tLx} = \frac{\tau_{tH}^{-1/e_{tH}}}{\pi}\tau_{tLi}^{-(1-e_{tL})/e_{tL}} + A(1 + \frac{1 - e_{tL}}{e_{tL}}\frac{\tau_{tH}^{-1/e_{tH}}\ \tau_{tLi}^{-1/e_{tL}}}{\pi})^2$$

$$\tau_{tLx} = \frac{0{,}77897^{-1/0{,}89}}{1{,}55169}0{,}85698^{-(1/0{,}91)/0{,}91} +$$

$$3{,}72x\ 10^{-3}(1+\frac{1-0{,}91}{0{,}91}\frac{0{,}77897^{-1/0{,}89}x\ 0{,}85698^{-1/0{,}91}}{1{,}55169})^2$$

$$\tau_{tLx} = 0{,}870886$$

$$\tau_{tLxx} = \frac{\tau_{tH}^{-1/e_{tH}}}{\pi}\tau_{tLx}^{-(1-e_{tL})/e_{tL}} + A(1+\frac{1-e_{tL}}{e_{tL}}\frac{\tau_{tH}^{-1/e_{tH}}\ \tau_{tLx}^{-1/e_{tL}}}{\pi})^2$$

$$\tau_{tLxx} = \frac{0{,}77897^{-1/0{,}89}}{1{,}55169}0{,}870886^{-(1/0{,}91)/0{,}91} +$$

$$3{,}72x\ 10^{-3}(1+\frac{1-0{,}91}{0{,}91}\frac{0{,}77897^{-1/0{,}89}x\ 0{,}870886^{-1/0{,}91}}{1{,}55169})^2$$

$$\tau_{tLxx} = 0{,}86949$$

$$\tau_{tLxxx} = \frac{\tau_{tH}^{-1/e_{tH}}}{\pi}\tau_{tLxx}^{-(1-e_{tL})/e_{tL}} + A(1+\frac{1-e_{tL}}{e_{tL}}\frac{\tau_{tH}^{-1/e_{tH}}\ \tau_{tLxx}^{-1/e_{tL}}}{\pi})^2$$

$$\tau_{tLxxx} = \frac{0{,}77897^{-1/0{,}89}}{1{,}55169}0{,}86949^{-(1/0{,}91)/0{,}91} +$$

$$3{,}72x\ 10^{-3}(1+\frac{1-0{,}91}{0{,}91}\frac{0{,}77897^{-1/0{,}89}x\ 0{,}86949^{-1/0{,}91}}{1{,}55169})^2$$

$$\tau_{tLxxx} = 0{,}86963$$

$\tau_{tLxxx} - \tau_{tLxx} = 0{,}86963 - 0{,}86949 = 0{,}00014$ telah terpenuhi iterasi.

Sehingga nilai *Turbine Low Temperature Ratio* (τ_{tLi}^*) sebesar 0,86963

15) Menghitung *Turbine Low Pressure Ratio*:

$$\pi_{tL} = \tau_{tL}^{\frac{\gamma_t}{\gamma_t - 1 e_{tL}}}$$

$$\pi_{tL} = 0{,}86963^{\frac{1{,}3}{(1{,}3-1)0{,}91}} = 0{,}514419$$

16) Menghitung *Ratio Total Pressure dan Overall Pressure*:

$$\frac{P_{t9}}{P_0} = \pi_r\pi_d\pi_c\pi_b\pi_{tH}\pi_{tL}\pi_n$$

$$\frac{P_{t9}}{P_0} = 1{,}04004x\ 0{,}97\ x\ 7\ x\ 0{,}96\ x\ 0{,}29636\ x\ 0{,}514419x\ 0{,}99$$

$$\frac{P_{t9}}{P_0} = 1{,}02273$$

17) Menghitung rasio kecepatan aliran udara di *nozzle* dan *Sound Speed*:

$$\frac{V_9}{a_0} = \sqrt{\frac{2\tau_\lambda \tau_{tH} \tau_{tL}}{\gamma_c - 1}[1 - \left(\frac{P_{t9}}{P_9}\right)^{-(\gamma_t - 1)/\gamma_t}]}$$

dimana:

$$\frac{P_{t9}}{P_9} = \left(\frac{\gamma_t + 1}{2}\right)^{\gamma_{t/(\gamma_t - 1)}}$$

Maka:

$$\frac{P_{t9}}{P_9} = \left(\frac{1{,}3 + 1}{2}\right)^{1{,}3/(1{,}3-1)} = 1{,}83242$$

$$\frac{P_0}{P_9} = \frac{\frac{P_{t9}}{P_9}}{\frac{P_{t9}}{P_0}} = \frac{1{,}83242}{1{,}02273} = 1{,}79169$$

Sehingga:

$$\frac{V_9}{a_0} = \sqrt{\frac{2\ x\ 3{,}89534\ x\ 0{,}77897\ x\ 0{,}86963}{1{,}4 - 1}[1 - (1{,}83242)^{-(1{,}3-1)/1{,}3}]}$$

$$\frac{V_9}{a_0} = 1{,}31184$$

18) Menghitung Koefisien Kerja *Output Propeller*:

$$C_{prop} = \eta_{prop}\eta_g\eta_{mL}(1 + f)\tau_\lambda\tau_{tH}(1 - \tau_{tL})$$

$$C_{prop} = 0{,}83 x\ 0{,}99\ x\ 0{,}99(1 + 0{,}01408)\ 3{,}89534\ x\ 0{,}77897(1 - 0{,}86963)$$

$$C_{prop} = 0{,}32633$$

19) Menghitung Koefisien Kerja *Compressor Core:*

$$C_c = (\gamma_c - 1)M_0[(1 + f)\frac{V_9}{a_0} - M_0 + (1 + f)\frac{R_t}{R_c}\frac{\frac{T_9}{T_0}}{\frac{V_9}{a_0}} - \frac{1 - \frac{P_0}{P_9}}{\gamma_c}$$

dimana:

$$\frac{T_9}{T_0} = \frac{\frac{T_{t9}}{T_0}}{\left(\frac{P_{t9}}{P_9}\right)^{(\gamma_t - 1)/\gamma_t}}$$

dan

$$\frac{T_{t9}}{T_0} = \frac{T_{t4}}{T_0}\tau_{tH}\tau_{tL}$$

$$\frac{T_{t9}}{T_0} = \frac{1.744,67}{515,07} 0,77897 x\ 0,86963 = 2,29457$$

Maka:

$$\frac{T_9}{T_0} = \frac{2,29457}{(1,83242)^{(1,3-1)/1,3}} = 1,99528$$

Sehingga:

$$C_c = (1,4 - 1)0,237496(1 + 0,01408)1,31184 - 0,237496 + (1 + 0,01408)\frac{49,56281}{53,35954}\frac{1,99528}{1,31184} - \frac{1 - 1,79169}{1,4}$$

$$C_c = 0,02685$$

20) Menghitung koefisien kerja *output* pada *engine core total:*

$$C_{tot} = C_{prop} + C_c$$

$$C_{tot} = 0,32633 + 0,02685$$

$$C_{tot} = 0,35318$$

21) Menghitung *Thrust and Mass Flow Ratio*:

$$\frac{F}{\dot{m}_0} = \frac{C_{tot}C_{pc}T_0}{V_0}$$

$$\frac{F}{\dot{m}_0} = \frac{0,35318\ x\ 0,24\ x\ 515,07}{264,2485}$$

$$\frac{F}{\dot{m}_0} = 216,9764\ lbf/(lbm/sec)$$

22) Menghitung *Specific Fuel Consumption:*

$$S = \frac{f}{F/\dot{m}_0}$$

$$S = \frac{0{,}01408\ x\ 3600}{216{,}976} = 0{,}23358\ (lbm/hr)/lbf$$

23) Menghitung *Specific Power*:

$$\frac{\dot{W}}{\dot{m}_0} = C_{tot} C_{pc} T_0$$

$$\frac{\dot{W}}{\dot{m}_0} = 0{,}35318\ x\ 0{,}24\ x\ 515{,}07$$

$$\frac{\dot{W}}{\dot{m}_0} = 43{,}65917\ hp/(lbm/sec)$$

24) Menghitung *Efficiency Thermal*, *Propulsive*, *Overall*

$$\eta T = \frac{0{,}35318}{\frac{0{,}01408\ x\ 18.400}{0{,}276 x\ 515{,}07}} = 16{,}9\%$$

$$\eta P = \frac{0{,}35318}{\left(\frac{0{,}32633}{0{,}83}\right) + \left(\frac{1{,}4-1}{2}\right) x\ (1 + 0{,}01408) x\ [(1{,}31184)^2 - 0{,}237496^2]}$$

$$\eta P = 48{,}3\%$$

$$\eta O = 16{,}9\%\ x\ 48{,}3\% = 8{,}2\%$$

17. Perhitungan *performance* setelah *TBO Extension* (5.600 *hours*) pada ketinggian 10.500 ft berdasarkan data *Aircraft Flight Log (AFL*. Tabel 1.18 merupakan parameter *input engine TBO extension* 5.600 *hours*.

Tabel 1.18 Parameter *Input Engine TBO* 3600 *hours*

Parameter	*Input*	Satuan
T_0	513,27	^{0}R
Tt_4	1.744,67	^{0}R

Perhitungan:

1) Menghitung konstanta gas di kompresor:

$$R_c = \frac{\gamma_c - 1}{\gamma_c} C_{pc}$$

$$R_c = \frac{1,4 - 1}{1,4} 0,24$$

$$R_c = 0,06857\ BTU/lbm.°R$$

$$R_c = 0,06857\ x\ 778,16\ ft.lbf/lbm.°R$$

$$R_c = 53,35954\ ft.lbf/lbm.°R$$

2) Menghitung konstanta gas di t*urbine*:

$$R_t = \frac{\gamma_t - 1}{\gamma_t} C_{pt}$$

$$R_t = \frac{1,3-1}{1,3} 0,276 = 0,63692\ BTU/lbm.°R$$

$$R_t = 0,63692\ x\ 778,16\ \ ft.lbf/bm.°R$$

$$R_t = 49,56281\ \ ft.lbf/bm.°R$$

3) Menghitung *Sound Speed* atau kecepatan suara:

$$a_0 = \sqrt{\gamma_c\ R_c\ \ g_c\ T_0}$$

$$a_0 = \sqrt{1,4\ \text{x}\ \ 53,35954\ x\ 32,174\ x\ 513,27}$$

$$a_0 = 1.110,69684\ ft/sec$$

4) Menghitung *Absolute velocity*:

V_0= TAS=$(\frac{FL}{1.000}\ x\ 2\%\ x\ 0,98\ x\ IAS) + IAS$

V_0= $(\frac{10500}{1000}\ x\ 2\%\ x\ 0,98\ x\ 130) + 130$

V_0= $156,754\ knot$

V_0= $156,754\ NM/hr$

V_0= $156,754\ x\ 1,852\ km/hr$

V_0= $290,308\ km/hr$

V_0= $80,641\ m/sec$

V_0= $80,641 x\ 3,2808 = 264,5449\ ft/sec$

5) Menghitung $Ratio\ Temperature\ Ram$:

$$\tau_r = 1 + \frac{\gamma_c - 1}{2} M_0^2$$

$dimana$:

$$M_0 = V_0/a_0$$

$$M_0 = \frac{264{,}5449}{1.110{,}69684} = 0{,}238179 Mach$$

$$\tau_r = 1 + \frac{1{,}4 - 1}{2} 0{,}238179^2$$

$$\tau_r = 1{,}01135$$

6) Menghitung $Ram\ Pressure\ Ratio$:

$$\pi_r = \tau_r{}^{\gamma_c/\,(\gamma_c - 1)}$$

$$\pi_r = 1{,}01135^{1{,}4/\,(1{,}4-1)} = 1{,}04028$$

7) Menghitung *Inlet Pressure Ratio:*

$$\pi_d = \pi_{dmax}\ x\ \eta_r$$

Dimana:

η_r= 1 untuk $M_0 \leq 1$

$\eta_r = 1 - 0{,}0075(M_0 - 1)^{1{,}35}$ untuk $M_0 \geq 1$

$$\pi_d = 0{,}97\ x\ 1 = 0{,}97$$

8) Menghitung *entalphy ratio* di ruang bakar dengan *ambient temperature* pada ketinggian terbang:

$$\tau_\lambda = \frac{C_{pt}\ x\ T_{t4}}{C_{pc} T_0}$$

$$\tau_\lambda = \frac{0{,}276\ x 1.744{,}67}{0{,}24\ x\ 513{,}27} = 3{,}909$$

9) Menghitung *temperature ratio* di ruang bakar dengan *ambient temperature* pada ketinggian terbang :

$$\tau_c = \pi_c^{(\gamma_c - 1)/\,(\gamma_c\, \varepsilon_c)}$$

$$\tau_c = 7^{(1{,}4-1)/\,(1{,}4\ x\ 0{,}90)} = 1{,}85475$$

10) Menghitung *Compressor Efficiency*:

$$\eta_c = \frac{\pi_c^{(\gamma_c - 1)/\gamma_c} - 1}{\tau_c - 1}$$

$$\eta_c = \frac{7^{(1{,}4-1)/1{,}4} - 1}{1{,}85475 - 1} = 0{,}87001$$

11) Menghitung *Fuel/Air Ratio:*

$$f = \frac{\tau_\lambda - \tau_r \tau_c}{\eta_b h_{PR}/(C_{pc} T_0) - \tau_\lambda}$$

$$f = \frac{3{,}909 - 1{,}01135\ x\ 1{,}85475}{0{,}99\ x\ 18.400/(0{,}24\ x\ 513{,}27) - 3{,}909} = 0{,}014123$$

12) Menghitung *High Temperature Turbine*:

$$\tau_{tH} = 1 - \frac{\tau_r(\tau_c - 1)}{\eta_{mH}(1+f)\tau_\lambda}$$

$$\tau_{tH} = 1 - \frac{1{,}01135\ \ (1{,}85475 - 1)}{0{,}99(1 + 0{,}014123)3{,}909} = 0{,}77973$$

13) Menghitung *Turbine High Temperature Ratio*:

$$\pi_{tH} = \tau_{tH}^{\gamma_{t}/[(\gamma_t - 1)e_{tH}]}$$

$$\pi_{tH} = 0{,}77973^{\frac{1{,}3}{(1{,}3-1)0{,}89}} = 0{,}29778$$

14) Menghitung *Turbine Low Temperature Ratio*:

$$\tau_{tLi}^{*} = \frac{\tau_{tH}^{-1/e_{tH}}}{\pi} + A$$

Dimana

$$\pi = (\pi_r \pi_d \pi_c \pi_b \pi_n)^{(\gamma_t - 1)/\,\gamma_t}$$

dan

$$A = \frac{\left[\frac{\gamma_c - 1}{2}\right]\left[\frac{M_0^2}{(\tau_\lambda \tau_{tH})}\right]}{(\eta_{prop}\eta_g\eta_{mL})^2}$$

$maka$:

$$\pi = (1{,}04028\ x\ 0{,}97\ x\ 7\ x\ 0{,}96\ x\ 0{,}99)^{(1{,}3-1)/\ 1{,}3} = 1{,}55178$$

dan

$$A = \frac{\left[\frac{1{,}4 - 1}{2}\right]\left[\frac{0{,}238179^2}{(3{,}909\ x\ 0{,}77973)}\right]}{(0{,}83x\ 0{,}99\ x\ 0{,}99)^2} = 3{,}72x\ 10^{-3}$$

Selanjutnya nilai τ_{tLi}^* dilakukan iterasi sampai nilainya mendekati 0,0001.

$$\tau_{tLi}^* = \frac{0{,}77973^{-1/0{,}89}}{1{,}55178} + 3{,}72x\ 10^{-3} = 0{,}856$$

$$\tau_{tLx} = \frac{\tau_{tH}^{-1/e_{tH}}}{\pi}\tau_{tLi}^{-(1-e_{tL})/e_{tL}} + A(1 + \frac{1-e_{tL}}{e_{tL}}\frac{\tau_{tH}^{-1/e_{tH}}\ \tau_{tLi}^{-1/e_{tL}}}{\pi})^2$$

$$\tau_{tLx} = \frac{0{,}77973^{-1/0{,}89}}{1{,}55178}0{,}856^{-(1/0{,}91)/0{,}91} +$$

$$3{,}72x\ 10^{-3}(1 + \frac{1-0{,}91}{0{,}91}\frac{0{,}77973^{-1/0{,}89}x\ 0{,}856^{-1/0{,}91}}{1{,}55178})^2$$

$$\tau_{tLx} = 0{,}869986$$

$$\tau_{tLxx} = \frac{\tau_{tH}^{-1/e_{tH}}}{\pi}\tau_{tLx}^{-(1-e_{tL})/e_{tL}} + A(1 + \frac{1-e_{tL}}{e_{tL}}\frac{\tau_{tH}^{-1/e_{tH}}\ \tau_{tLx}^{-1/e_{tL}}}{\pi})^2$$

$$\tau_{tLxx} = \frac{0{,}77973^{-1/0{,}89}}{1{,}55178}0{,}869986^{-(1/0{,}91)/0{,}91} +$$

$$3{,}72x\ 10^{-3}(1 + \frac{1-0{,}91}{0{,}91}\frac{0{,}77973^{-1/0{,}89}x\ 0{,}869986^{-1/0{,}91}}{1{,}55178})^2$$

$$\tau_{tLxx} = 0{,}86859$$

$$\tau_{tLxxx} = \frac{\tau_{tH}^{-1/e_{tH}}}{\pi}\tau_{tLxx}^{-(1-e_{tL})/e_{tL}} + A(1 + \frac{1-e_{tL}}{e_{tL}}\frac{\tau_{tH}^{-1/e_{tH}}\ \tau_{tLxx}^{-1/e_{tL}}}{\pi})^2$$

$$\tau_{tLxxx} = \frac{0{,}77973^{-1/0{,}89}}{1{,}55178} 0{,}86859^{-(1/0{,}91)/0{,}91} +$$

$$3{,}72x\ 10^{-3}(1 + \frac{1-0{,}91}{0{,}91} \frac{0{,}77973^{-1/0{,}89} x\ 0{,}86859^{-1/0{,}91}}{1{,}55178})^2$$

$$\tau_{tLxxx} = 0{,}86872$$

$\tau_{tLxxx} - \tau_{tLxx} = 0{,}86872 - 0{,}86859 = 0{,}00013$ telah terpenuhi iterasi.

Sehingga nilai *Turbine Low Temperature Ratio* (τ^*_{tLi}) sebesar 0,86872

15) Menghitung *Turbine Low Pressure Ratio*:

$$\pi_{tL} = \tau_{tL}^{\gamma \frac{t}{\gamma_t - 1 e_{tL}}}$$

$$\pi_{tL} = 0{,}86872^{\frac{1{,}3}{(1{,}3-1)0{,}91}} = 0{,}51164$$

16) Menghitung *Ratio Total Pressure dan Overall Pressure*:

$$\frac{P_{t9}}{P_0} = \pi_r \pi_d \pi_c \pi_b \pi_{tH} \pi_{tL} \pi_n$$

$$\frac{P_{t9}}{P_0} = 1{,}04028x\ 0{,}97\ x\ 7\ x\ 0{,}96\ x\ 0{,}29778\ x\ 0{,}51164x\ 0{,}99$$

$$\frac{P_{t9}}{P_0} = 1{,}02278$$

17) Menghitung rasio kecepatan aliran udara di *nozzle* dan *Sound Speed*:

$$\frac{V_9}{a_0} = \sqrt{\frac{2\tau_\lambda \tau_{tH} \tau_{tL}}{\gamma_c - 1} [1 - \left(\frac{P_{t9}}{P_9}\right)^{-(\gamma_t - 1)/\gamma_t}]}$$

$dimana$:

$$\frac{P_{t9}}{P_9} = \left(\frac{\gamma_t + 1}{2}\right)^{\gamma_{t/(\gamma_t - 1)}}$$

Maka:

$$\frac{P_{t9}}{P_9} = \left(\frac{1{,}3+1}{2}\right)^{1{,}3/(1{,}3-1)} = 1{,}83242$$

$$\frac{P_0}{P_9} = \frac{\frac{P_{t9}}{P_9}}{\frac{P_{t9}}{P_0}} = \frac{1{,}83242}{1{,}02278} = 1{,}79159$$

Sehingga:

$$\frac{V_9}{a_0} = \sqrt{\frac{2\ x\ 3{,}909\ x\ 0{,}779733\ x\ 0{,}86872}{1{,}4-1}\left[1-(1{,}83242)^{-(1{,}3-1)/1{,}3}\right]}$$

$$\frac{V_9}{a_0} = 1{,}3141$$

18) Menghitung Koefisien Kerja *Output Propeller*:

$$C_{prop} = \eta_{prop}\eta_g\eta_{mL}(1+f)\tau_\lambda\tau_{tH}(1-\tau_{tL})$$

$$C_{prop} = 0{,}83x\ 0{,}99\ x\ 0{,}99(1+0{,}014123)\ 3{,}909\ x\ 0{,}77973(1-0{,}86872)$$

$$C_{prop} = 0{,}33009$$

19) Menghitung Koefisien Kerja *Compressor Core:*

$$C_c = (\gamma_c - 1)M_0[(1+f)\frac{V_9}{a_0} - M_0 + (1+f)\frac{R_t}{R_c}\frac{\frac{T_9}{T_0}}{\frac{V_9}{a_0}} - \frac{1-\frac{P_0}{P_9}}{\gamma_c}$$

dimana:

$$\frac{T_9}{T_0} = \frac{\frac{T_{t9}}{T_0}}{\left(\frac{P_{t9}}{P_9}\right)^{(\gamma_t-1)/\gamma_t}}$$

dan

$$\frac{T_{t9}}{T_0} = \frac{T_{t4}}{T_0}\tau_{tH}\tau_{tL}$$

$$\frac{T_{t9}}{T_0} = \frac{1.744{,}67}{513{,}27}0{,}77973x\ 0{,}86872 = 2{,}30248$$

Maka:

$$\frac{T_9}{T_0} = \frac{2{,}30248}{(1{,}83242)^{(1{,}3-1)/1{,}3}} = 2{,}00216$$

Sehingga:

$$C_c = (1{,}4-1)0{,}238179(1+0{,}014123)1{,}3141 - 0{,}238179 + (1+0{,}014123)\frac{49{,}56281}{53{,}35954}\frac{2{,}00216}{1{,}31184} - \frac{1-1{,}79159}{1{,}4}$$

$$C_c = 0{,}02696$$

20) Menghitung koefisien kerja *output* pada *engine core total:*

$$C_{tot} = C_{prop} + C_c$$

$$C_{tot} = 0{,}33009 + 0{,}02696$$

$$C_{tot} = 0{,}35705$$

21) Menghitung *Thrust and Mass Flow Ratio*:

$$\frac{F}{\dot{m}_0} = \frac{C_{tot}C_{pc}T_0}{V_0}$$

$$\frac{F}{\dot{m}_0} = \frac{0{,}35705\ x\ 0{,}24\ x\ 513{,}27}{264{,}5449}$$

$$\frac{F}{\dot{m}_0} = 218{,}34377\ lbf/(lbm/sec)$$

22) Menghitung *Specific Fuel Consumption:*

$$S = \frac{f}{F/\dot{m}_0}$$

$$S = \frac{0{,}014123\ x\ 3600}{218{,}34377} = 0{,}23285\ (lbm/hr)/lbf$$

23) Menghitung *Specific Power*:

$$\frac{\dot{W}}{\dot{m}_0} = C_{tot}C_{pc}T_0$$

$$\frac{\dot{W}}{\dot{m}_0} = 0{,}35705\ x\ 0{,}24\ x\ 513{,}27$$

$$\frac{\dot{W}}{\dot{m}_0} = 43{,}98358\ hp/(lbm/sec)$$

24) Menghitung *Efficiency Thermal*, *Propulsive*, *Overall*

$$\eta T = \frac{0{,}35705}{\frac{0{,}014123\ x\ 18.400}{0{,}276 x\ 513{,}27}} = 16{,}9\%$$

$$\eta P = \frac{0{,}35705}{\left(\frac{0{,}33009}{0{,}83}\right) + \left(\frac{1{,}4-1}{2}\right) x\ (1 + 0{,}014123) x\ [(1{,}341)^2 - 0{,}238179^2]}$$

$$\eta P = 48{,}5\%$$

$$\eta O = 16{,}9\%\ x\ 48{,}5\% = 8{,}2\%$$

18. Perhitungan *performance* setelah *TBO Extension* (5.600 *hours*) pada ketinggian 11.500 ft berdasarkan data *Aircraft Flight Log (AFL)*. Tabel 1.19 merupakan parameter *input engine TBO extension* 5.600 *hours*.

Tabel 1.19 Parameter *Input Engine TBO* 3600 *hours*

Parameter	*Input*	Satuan
T_0	506,07	^{0}R
Tt_4	1733,67	^{0}R

Perhitungan:

1) Menghitung konstanta gas di kompresor:

$$R_c = \frac{\gamma_c - 1}{\gamma_c} C_{pc}$$

$$R_c = \frac{1{,}4 - 1}{1{,}4} 0{,}24$$

$$R_c = 0{,}06857\ BTU/lbm.°R$$

$$R_c = 0{,}06857\ x\ 778{,}16\ ft.lbf/lbm.°R$$

$$R_c = 53{,}35954\ ft.lbf/lbm.°R$$

2) Menghitung konstanta gas di t*urbine*:

$$R_t = \frac{\gamma_t - 1}{\gamma_t} C_{pt}$$

$R_t = \frac{1,3-1}{1,3} 0,276 \; = 0,63692 \; BTU/lbm.°R$

$R_t = 0,63692 \; x \; 778,16 \;\; ft.lbf/bm.°R$

$R_t = 49,56281 \;\; ft.lbf/bm.°R$

3) Menghitung *Sound Speed* atau kecepatan suara:

$a_0 = \sqrt{\gamma_c \, R_c \;\, g_c \, T_0}$

$a_0 = \sqrt{1,4 \text{ x } \; 53,35954 \; x \; 32,174 \; x \; 506,07}$

$a_0 = 1.102,87907 ft/sec$

4) Menghitung *Absolute velocity*:

V_0= TAS=$(\frac{FL}{1.000} x \; 2\% \; x \; 0,98 \; x \; IAS) + IAS$

V_0= $(\frac{11500}{1000} x \; 2\% \; x \; 0,98 \; x \; 132) + 132$

V_0= $161,757 knot$

V_0= $161,757 NM/hr$

V_0= $161,757 x \; 1,852 \; km/hr$

V_0= $299,566 \; km/hr$

V_0= $83,213 \; m/sec$

V_0= $83,213 x \; 3,2808 = 272,9811 \; ft/sec$

5) Menghitung $Ratio \; Temperature \; Ram$:

$$\tau_r = 1 + \frac{\gamma_c - 1}{2} M_0^2$$

$dimana$:

$M_0 = V_0/a_0$

$M_0 = \frac{272,9811}{1.102,87907} = 0,247517 Mach$

$$\tau_r = 1 + \frac{1,4-1}{2} 0,247517^2$$

$\tau_r = 1,01225$

6) Menghitung $Ram \; Pressure \; Ratio$:

$\pi_r = \tau_r^{\gamma_c/\,(\gamma_c-1)}$

$\pi_r = 1{,}01225^{1{,}4/\,(1{,}4-1)} = 1{,}014355$

7) Menghitung *Inlet Pressure Ratio:*

$\pi_d = \pi_{dmax}\; x\; \eta_r$

Dimana:

η_r= 1 untuk $M_0 \leq 1$

$\eta_r = 1 - 0{,}0075(M_0 - 1)^{1{,}35}$ untuk $M_0 \geq 1$

$\pi_d = 0{,}97\; x\; 1 = 0{,}97$

8) Menghitung *entalphy ratio* di ruang bakar dengan *ambient temperature* pada ketinggian terbang:

$$\tau_\lambda = \frac{C_{pt}\; x\; T_{t4}}{C_{pc}T_0}$$

$$\tau_\lambda = \frac{0{,}276\; x 1733{,}67}{0{,}24\; x\; 506{,}07} = 3{,}93961$$

9) Menghitung *temperature ratio* di ruang bakar dengan *ambient temperature* pada ketinggian terbang :

$\tau_c = \pi_c^{(\gamma_c-1)/\,(\gamma_c\,\varepsilon_c)}$

$\tau_c = 7^{(1{,}4-1)/\,(1{,}4\; x\; 0{,}90)} = 1{,}85475$

10) Menghitung *Compressor Efficiency*:

$$\eta_c = \frac{\pi_c^{(\gamma_c-1)/\gamma_c} - 1}{\tau_c - 1}$$

$$\eta_c = \frac{7^{(1{,}4-1)/1{,}4} - 1}{1{,}85475 - 1} = 0{,}87001$$

11) Menghitung *Fuel/Air Ratio:*

$$f = \frac{\tau_\lambda - \tau_r\tau_c}{\eta_b h_{PR}/(C_{pc}T_0) - \tau_\lambda}$$

$$f = \frac{3{,}93961 - 1{,}01225\; x\; 1{,}85475}{0{,}99\; x\; 18.400/(0{,}24\; x\; 506{,}07) - 3{,}93961} = 0{,}0141204$$

12) Menghitung *High Temperature Turbine*:

$$\tau_{tH} = 1 - \frac{\tau_r(\tau_c - 1)}{\eta_{mH}(1+f)\tau_\lambda}$$

$$\tau_{tH} = 1 - \frac{1{,}01225\ \ (1{,}85475 - 1)}{0{,}99(1 + 0{,}0141204)3{,}93961} = 0{,}78125$$

13) Menghitung *Turbine High Temperature Ratio*:

$$\pi_{tH} = \ \tau_{tH}^{\gamma_t/[(\gamma_t - 1)e_{tH}]}$$

$$\pi_{tH} = \ 0{,}78125^{\frac{1{,}3}{(1{,}3-1)0{,}89}} = 0{,}30061$$

14) Menghitung *Turbine Low Temperature Ratio*:

$$\tau_{tLi}^{*} = \frac{\tau_{tH}^{-1/e_{tH}}}{\pi} + A$$

Dimana

$$\pi = (\pi_r \pi_d \pi_c \pi_b \pi_n)^{(\gamma_t - 1)/\ \gamma_t}$$

dan

$$A = \frac{\left[\frac{\gamma_c - 1}{2}\right]\left[\frac{M_0^2}{(\tau_\lambda\, \tau_{tH})}\right]}{(\eta_{prop}\eta_g\eta_{mL})^2}$$

$maka$:

$$\pi = (1{,}014355\ x\ 0{,}97\ x\ 7\ x\ 0{,}96\ x\ 0{,}99)^{(1{,}3-1)/\ 1{,}3} = 1{,}5529$$

dan

$$A = \frac{\left[\frac{1{,}4 - 1}{2}\right]\left[\frac{0{,}247517^2}{(3{,}93961\ x\ 0{,}78125)}\right]}{(0{,}83x\ 0{,}99\ x\ 0{,}99)^2} = 3{,}98x\ 10^{-3}$$

Selanjutnya nilai τ_{tLi}^{*} dilakukan iterasi sampai nilainya mendekati 0,0001.

$$\tau_{tLi}^{*} = \frac{0{,}78125^{-1/0{,}89}}{1{,}5529} + 3{,}98x\ 10^{-3} = 0{,}85378$$

$$\tau_{tLx} = \frac{\tau_{tH}^{-1/e_{tH}}}{\pi} \tau_{tLi}^{-(1-e_{tL})/e_{tL}} + A(1 + \frac{1-e_{tL}}{e_{tL}} \frac{\tau_{tH}^{-1/e_{tH}} \; \tau_{tLi}^{-1/e_{tL}}}{\pi})^2$$

$$\tau_{tLx} = \frac{0{,}78125^{-1/0{,}89}}{1{,}5529} 0{,}85378^{-(1/0{,}91)/0{,}91} +$$

$$3{,}98x\ 10^{-3}(1 + \frac{1-0{,}91}{0{,}91} \frac{0{,}78125^{-1/0{,}89} x\ 0{,}85378^{-1/0{,}91}}{1{,}5529})^2$$

$$\tau_{tLx} = 0{,}868009$$

$$\tau_{tLxx} = \frac{\tau_{tH}^{-1/e_{tH}}}{\pi} \tau_{tLx}^{-(1-e_{tL})/e_{tL}} + A(1 + \frac{1-e_{tL}}{e_{tL}} \frac{\tau_{tH}^{-1/e_{tH}} \; \tau_{tLx}^{-1/e_{tL}}}{\pi})^2$$

$$\tau_{tLxx} = \frac{0{,}78125^{-1/0{,}89}}{1{,}5529} 0{,}868009^{-(1/0{,}91)/0{,}91} +$$

$$3{,}98x\ 10^{-3}(1 + \frac{1-0{,}91}{0{,}91} \frac{0{,}78125^{-1/0{,}89} x\ 0{,}868009^{-1/0{,}91}}{1{,}5529})^2$$

$$\tau_{tLxx} = 0{,}86658$$

$$\tau_{tLxxx} = \frac{\tau_{tH}^{-1/e_{tH}}}{\pi} \tau_{tLxx}^{-(1-e_{tL})/e_{tL}} + A(1 + \frac{1-e_{tL}}{e_{tL}} \frac{\tau_{tH}^{-1/e_{tH}} \; \tau_{tLxx}^{-1/e_{tL}}}{\pi})^2$$

$$\tau_{tLxxx} = \frac{0{,}78125^{-1/0{,}89}}{1{,}5529} 0{,}86658^{-(1/0{,}91)/0{,}91} +$$

$$3{,}98x\ 10^{-3}(1 + \frac{1-0{,}91}{0{,}91} \frac{0{,}78125^{-1/0{,}89} x\ 0{,}86658^{-1/0{,}91}}{1{,}5529})^2$$

$$\tau_{tLxxx} = 0{,}86673$$

$\tau_{tLxxx} - \tau_{tLxx} = 0{,}86673 - 0{,}86658 = 0{,}00015$ telah terpenuhi iterasi.

Sehingga nilai *Turbine Low Temperature Ratio* (τ_{tLi}^{*}) sebesar 0,86673

15) Menghitung *Turbine Low Pressure Ratio*:

$$\pi_{tL} = \tau_{tL}^{\frac{\gamma_t}{\gamma_t - 1 e_{tL}}}$$

$$\pi_{tL} = 0{,}86673^{\frac{1{,}3}{(1{,}3-1)0{,}91}} = 0{,}50605$$

16) Menghitung *Ratio Total Pressure dan Overall Pressure*:

$$\frac{P_{t9}}{P_0} = \pi_r \pi_d \pi_c \pi_b \pi_{tH} \pi_{tL} \pi_n$$

$$\frac{P_{t9}}{P_0} = 1{,}014355 x\ 0{,}97\ x\ 7\ x\ 0{,}96\ x\ 0{,}30061\ x\ 0{,}50605 x\ 0{,}99$$

$$\frac{P_{t9}}{P_0} = 1{,}02444$$

17) Menghitung rasio kecepatan aliran udara di *nozzle* dan *Sound Speed*:

$$\frac{V_9}{a_0} = \sqrt{\frac{2\tau_\lambda \tau_{tH} \tau_{tL}}{\gamma_c - 1}\left[1 - \left(\frac{P_{t9}}{P_9}\right)^{-(\gamma_t - 1)/\gamma_t}\right]}$$

dimana:

$$\frac{P_{t9}}{P_9} = \left(\frac{\gamma_t + 1}{2}\right)^{\gamma_{t/(\gamma_t - 1)}}$$

Maka:

$$\frac{P_{t9}}{P_9} = \left(\frac{1{,}3 + 1}{2}\right)^{1{,}3/(1{,}3-1)} = 1{,}83242$$

$$\frac{P_0}{P_9} = \frac{\frac{P_{t9}}{P_9}}{\frac{P_{t9}}{P_0}} = \frac{1{,}83242}{1{,}02444} = 1{,}78869$$

Sehingga:

$$\frac{V_9}{a_0} = \sqrt{\frac{2\ x\ 3{,}93961\ x\ 0{,}78125\ x\ 0{,}86673}{1{,}4 - 1}\left[1 - (1{,}83242)^{-(1{,}3-1)/1{,}3}\right]}$$

$$\frac{V_9}{a_0} = 1{,}319$$

18) Menghitung Koefisien Kerja *Output Propeller*:

$$C_{prop} = \eta_{prop} \eta_g \eta_{mL} (1 + f) \tau_\lambda \tau_{tH} (1 - \tau_{tL})$$

$$C_{prop} = 0{,}83 x\ 0{,}99\ x\ 0{,}99(1 + 0{,}0141204)\ 3{,}93961\ x\ 0{,}78125(1 - 0{,}86673)$$

$$C_{prop} = 0{,}3284$$

19) Menghitung Koefisien Kerja *Compressor Core:*

$$C_c = (\gamma_c - 1)M_0[(1+f)\frac{V_9}{a_0} - M_0 + (1+f)\frac{R_t}{R_c}\frac{\frac{T_9}{T_0}}{\frac{V_9}{a_0}} - \frac{1-\frac{P_0}{P_9}}{\gamma_c}$$

$dimana$:

$$\frac{T_9}{T_0} = \frac{\frac{T_{t9}}{T_0}}{\left(\frac{P_{t9}}{P_9}\right)^{(\gamma_t-1)/\gamma_t}}$$

dan

$$\frac{T_{t9}}{T_0} = \frac{T_{t4}}{T_0}\tau_{tH}\tau_{tL}$$

$$\frac{T_{t9}}{T_0} = \frac{1733{,}67}{506{,}07}0{,}78125x\ 0{,}86673 = 2{,}31967$$

Maka:

$$\frac{T_9}{T_0} = \frac{2{,}31967}{(1{,}83242)^{(1{,}3-1)/1{,}3}} = 2{,}01711$$

Sehingga:

$$C_c = (1{,}4-1)0{,}247517(1+0{,}0141204)1{,}319 - 0{,}247517 + (1+0{,}0141204)\frac{49{,}56281}{53{,}35954}\frac{2{,}01711}{1{,}319} - \frac{1-1{,}78869}{1{,}4}$$

$$C_c = 0{,}02758$$

20) Menghitung koefisien kerja *output* pada *engine core total:*

$$C_{tot} = C_{prop} + C_c$$

$$C_{tot} = 0{,}3284 + 0{,}02758$$

$$C_{tot} = 0{,}36598$$

21) Menghitung *Thrust and Mass Flow Ratio*:

$$\frac{F}{\dot{m}_0} = \frac{C_{tot}C_{pc}T_0}{V_0}$$

$$\frac{F}{\dot{m}_0} = \frac{0{,}36598\ x\ 0{,}24\ x\ 506{,}07}{272{,}9811}$$

$$\frac{F}{\dot{m}_0} = 213{,}84414\ lbf/(lbm/sec)$$

22) Menghitung *Specific Fuel Consumption:*

$$S = \frac{f}{F/\dot{m}_0}$$

$$S = \frac{0{,}0141204\ x\ 3600}{213{,}84414} = 0{,}23771\ (lbm/hr)/lbf$$

23) Menghitung *Specific Power*:

$$\frac{\dot{W}}{\dot{m}_0} = C_{tot}C_{pc}T_0$$

$$\frac{\dot{W}}{\dot{m}_0} = 0{,}36598\ x\ 0{,}24\ x\ 506{,}07$$

$$\frac{\dot{W}}{\dot{m}_0} = 44{,}45087\ hp/(lbm/sec)$$

24) Menghitung *Efficiency Thermal*, *Propulsive*, *Overall*

$$\eta T = \frac{0{,}36598}{\frac{0{,}014355\ x\ 18.400}{0{,}276 x\ 506{,}07}} = 17{,}1\%$$

$$\eta P = \frac{0{,}36598}{\left(\frac{0{,}3284}{0{,}83}\right) + \left(\frac{1{,}4-1}{2}\right) x\ (1 + 0{,}014355) x\ [(1{,}319)^2 - 0{,}247517^2]}$$

$$\eta P = 48{,}9\%$$

$$\eta O = 17{,}1\%\ x\ 48{,}9\% = 8{,}4\%$$

19. Perhitungan *performance* setelah *TBO Extension* (5.600 *hours*) pada ketinggian 12.500 ft berdasarkan data *Aircraft Flight Log (AFL)*. Tabel 1.20 merupakan parameter *input engine TBO extension* 5.600 *hours*.

Tabel 1.20 Parameter *Input Engine TBO* 3600 *hours*

Parameter	*Input*	Satuan
T_0	504,27	^0R
Tt_4	1733,67	^0R

Perhitungan:

1) Menghitung konstanta gas di kompresor:

$$R_c = \frac{\gamma_c - 1}{\gamma_c} C_{pc}$$

$$R_c = \frac{1,4 - 1}{1,4} 0,24$$

$$R_c = 0,06857\ BTU/lbm.°R$$

$$R_c = 0,06857\ x\ 778,16\ ft.lbf/lbm.°R$$

$$R_c = 53,35954\ ft.lbf/lbm.°R$$

2) Menghitung konstanta gas di t*urbine*:

$$R_t = \frac{\gamma_t - 1}{\gamma_t} C_{pt}$$

$$R_t = \frac{1,3-1}{1,3} 0,276 = 0,63692\ BTU/lbm.°R$$

$$R_t = 0,63692\ x\ 778,16\ \ ft.lbf/bm.°R$$

$$R_t = 49,56281\ \ ft.lbf/bm.°R$$

3) Menghitung *Sound Speed* atau kecepatan suara:

$$a_0 = \sqrt{\gamma_c\ R_c\ \ g_c\ T_0}$$

$$a_0 = \sqrt{1,4\ \text{x}\ \ 53,35954\ x\ 32,174\ x\ 504,27}$$

$$a_0 = 1.100,91595\ ft/sec$$

4) Menghitung *Absolute velocity*:

V_0= TAS=$(\frac{FL}{1.000}\ x\ 2\%\ x\ 0,98\ x\ IAS) + IAS$

V_0= $(\frac{12500}{1000}\ x\ 2\%\ x\ 0,98\ x\ 127) + 127$

V_0= $158,115 knot$

V_0= $158,115 NM/hr$

V_0= $158,115 x\ 1,852\ km/hr$

V_0= $292{,}829\ km/hr$

V_0= $81{,}341\ m/sec$

V_0= $81{,}341 x\ 3{,}2808 = 266{,}8418\ ft/sec$

5) Menghitung $Ratio\ Temperature\ Ram$:

$$\tau_r = 1 + \frac{\gamma_c - 1}{2} M_0^2$$

$dimana$:

$M_0 = V_0/a_0$

$M_0 = \frac{266{,}8418}{1.100{,}91595} = 0{,}242382 Mach$

$$\tau_r = 1 + \frac{1{,}4 - 1}{2} 0{,}242382^2$$

$\tau_r = 1{,}01175$

6) Menghitung $Ram\ Pressure\ Ratio$:

$\pi_r = \tau_r{}^{\gamma_c/\ (\gamma_c - 1)}$

$\pi_r = 1{,}01175^{1{,}4/\ (1{,}4-1)} = 1{,}04173$

7) Menghitung *Inlet Pressure Ratio:*

$\pi_d = \pi_{dmax}\ x\ \eta_r$

Dimana:

η_r= 1 untuk $M_0 \leq 1$

$\eta_r = 1 - 0{,}0075(M_0 - 1)^{1{,}35}$ untuk $M_0 \geq 1$

$\pi_d = 0{,}97\ x\ 1 = 0{,}97$

8) Menghitung *entalphy ratio* di ruang bakar dengan *ambient temperature* pada ketinggian terbang:

$$\tau_\lambda = \frac{C_{pt}\ x\ T_{t4}}{C_{pc} T_0}$$

$$\tau_\lambda = \frac{0{,}276\ x 1733{,}67}{0{,}24\ x\ 504{,}27} = 3{,}95368$$

9) Menghitung *temperature ratio* di ruang bakar dengan *ambient temperature* pada ketinggian terbang :

$$\tau_c = \pi_c^{(\gamma_c - 1)/\,(\gamma_c\ \varepsilon_c)}$$

$$\tau_c = 7^{(1{,}4-1)/\,(1{,}4\ x\ 0{,}90)} = 1{,}85475$$

10) Menghitung *Compressor Efficiency*:

$$\eta_c = \frac{\pi_c^{(\gamma_c - 1)/\gamma_c} - 1}{\tau_c - 1}$$

$$\eta_c = \frac{7^{(1{,}4-1)/1{,}4} - 1}{1{,}85475 - 1} = 0{,}87001$$

11) Menghitung *Fuel/Air Ratio:*

$$f = \frac{\tau_\lambda - \tau_r \tau_c}{\eta_b h_{PR}/(C_{pc} T_0) - \tau_\lambda}$$

$$f = \frac{3{,}95368 - 1{,}01175\ x\ 1{,}85475}{0{,}99\ x\ 18.400/(0{,}24\ x\ 504{,}27) - 3{,}95368} = 0{,}014173$$

12) Menghitung *High Temperature Turbine*:

$$\tau_{tH} = 1 - \frac{\tau_r(\tau_c - 1)}{\eta_{mH}(1 + f)\tau_\lambda}$$

$$\tau_{tH} = 1 - \frac{1{,}01175\ \ (1{,}85475 - 1)}{0{,}99(1 + 0{,}014173)3{,}95368} = 0{,}78215$$

13) Menghitung *Turbine High Temperature Ratio*:

$$\pi_{tH} = \tau_{tH}^{\gamma_t/[(\gamma_t - 1)e_{tH}]}$$

$$\pi_{tH} = 0{,}78215^{\frac{1{,}3}{(1{,}3-1)0{,}89}} = 0{,}30229$$

14) Menghitung *Turbine Low Temperature Ratio*:

$$\tau_{tLi}^{*} = \frac{\tau_{tH}^{-1/e_{tH}}}{\pi} + A$$

Dimana

$\pi = (\pi_r \pi_d \pi_c \pi_b \pi_n)^{(\gamma_t - 1)/\,\gamma_t}$

dan

$$A = \frac{\left[\frac{\gamma_c - 1}{2}\right]\left[\frac{M_0^2}{(\tau_\lambda\, \tau_{tH})}\right]}{(\eta_{prop}\eta_g\eta_{mL})^2}$$

$maka$:

$\pi = (1{,}04173\ x\ 0{,}97\ x\ 7\ x\ 0{,}96\ x\ 0{,}99)^{(1{,}3-1)/\,1{,}3} = 1{,}55228$

dan

$$A = \frac{\left[\frac{1{,}4 - 1}{2}\right]\left[\frac{0{,}242382^2}{(3{,}95368\ x\ 0{,}78215)}\right]}{(0{,}83x\ 0{,}99\ x\ 0{,}99)^2} = 3{,}8x\ 10^{-3}$$

Selanjutnya nilai τ_{tLi}^* dilakukan iterasi sampai nilainya mendekati 0,0001.

$$\tau_{tLi}^* = \frac{0{,}78215^{-1/0{,}89}}{1{,}55228} + 3{,}8x\ 10^{-3} = 0{,}85298$$

$$\tau_{tLx} = \frac{\tau_{tH}^{-1/e_{tH}}}{\pi}\tau_{tLi}^{-(1-e_{tL})/e_{tL}} + A(1 + \frac{1 - e_{tL}}{e_{tL}}\frac{\tau_{tH}^{-1/e_{tH}}\ \tau_{tLi}^{-1/e_{tL}}}{\pi})^2$$

$$\tau_{tLx} = \frac{0{,}78215^{-1/0{,}89}}{1{,}55228}0{,}85298^{-(1/0{,}91)/0{,}91} +$$

$$3{,}8x\ 10^{-3}(1 + \frac{1 - 0{,}91}{0{,}91}\frac{0{,}78215^{-1/0{,}89}x\ 0{,}85298^{-1/0{,}91}}{1{,}55228})^2$$

$\tau_{tLx} = 0{,}867117$

$$\tau_{tLxx} = \frac{\tau_{tH}^{-1/e_{tH}}}{\pi}\tau_{tLx}^{-(1-e_{tL})/e_{tL}} + A(1 + \frac{1 - e_{tL}}{e_{tL}}\frac{\tau_{tH}^{-1/e_{tH}}\ \tau_{tLx}^{-1/e_{tL}}}{\pi})^2$$

$$\tau_{tLxx} = \frac{0{,}78215^{-1/0{,}89}}{1{,}55228}0{,}867117^{-(1/0{,}91)/0{,}91} +$$

$$3{,}8x\ 10^{-3}(1 + \frac{1 - 0{,}91}{0{,}91}\frac{0{,}78215^{-1/0{,}89}x\ 0{,}867117^{-1/0{,}91}}{1{,}55228})^2$$

$\tau_{tLxx} = 0{,}86569$

$$\tau_{tLxxx} = \frac{\tau_{tH}^{-1/e_{tH}}}{\pi}\tau_{tLxx}^{-(1-e_{tL})/e_{tL}} + A(1 + \frac{1-e_{tL}}{e_{tL}}\frac{\tau_{tH}^{-1/e_{tH}}\ \tau_{tLxx}^{-1/e_{tL}}}{\pi})^2$$

$$\tau_{tLxxx} = \frac{0{,}78215^{-1/0{,}89}}{1{,}55228}0{,}86569^{-(1/0{,}91)/0{,}91} +$$

$$3{,}8x\ 10^{-3}(1 + \frac{1-0{,}91}{0{,}91}\frac{0{,}78215^{-1/0{,}89}x\ 0{,}86569^{-1/0{,}91}}{1{,}55228})^2$$

$$\tau_{tLxxx} = 0{,}86583$$

$\tau_{tLxxx} - \tau_{tLxx} = 0{,}86583 - 0{,}86569 = 0{,}00013$ telah terpenuhi iterasi.

Sehingga nilai *Turbine Low Temperature Ratio* (τ^*_{tLi}) sebesar 0,86583

15) Menghitung *Turbine Low Pressure Ratio*:

$$\pi_{tL} = \tau_{tL}^{\gamma\frac{t}{\gamma_t - 1 e_{tL}}}$$

$$\pi_{tL} = 0{,}86583^{\frac{1{,}3}{(1{,}3-1)0{,}91}} = 0{,}50357$$

16) Menghitung *Ratio Total Pressure dan Overall Pressure*:

$$\frac{P_{t9}}{P_0} = \pi_r\pi_d\pi_c\pi_b\pi_{tH}\pi_{tL}\pi_n$$

$$\frac{P_{t9}}{P_0} = 1{,}04173x\ 0{,}97\ x\ 7\ x\ 0{,}96\ x\ 0{,}30229\ x\ 0{,}50357x\ 0{,}99$$

$$\frac{P_{t9}}{P_0} = 1{,}02324$$

17) Menghitung rasio kecepatan aliran udara di *nozzle* dan *Sound Speed*:

$$\frac{V_9}{a_0} = \sqrt{\frac{2\tau_\lambda\tau_{tH}\tau_{tL}}{\gamma_c - 1}[1 - \left(\frac{P_{t9}}{P_9}\right)^{-(\gamma_t-1)/\gamma_t}]}$$

$dimana$:

$$\frac{P_{t9}}{P_9} = \left(\frac{\gamma_t + 1}{2}\right)^{\gamma_{t/(\gamma_t-1)}}$$

Maka:

$$\frac{P_{t9}}{P_9} = \left(\frac{1{,}3+1}{2}\right)^{1{,}3/(1{,}3-1)} = 1{,}83242$$

$$\frac{P_0}{P_9} = \frac{\frac{P_{t9}}{P_9}}{\frac{P_{t9}}{P_0}} = \frac{1,83242}{1,02324} = 1,79062$$

Sehingga:

$$\frac{V_9}{a_0} = \sqrt{\frac{2\ x\ 3,95368\ x\ 0,78215\ x\ 0,86583}{1,4 - 1}[1 - (1,83242)^{-(1,3-1)/1,3}]}$$

$$\frac{V_9}{a_0} = 1,32143$$

18) Menghitung Koefisien Kerja *Output Propeller*:

$$C_{prop} = \eta_{prop}\eta_g\eta_{mL}(1 + f)\tau_\lambda\tau_{tH}(1 - \tau_{tL})$$

$$C_{prop} = 0,83x\ 0,99\ x\ 0,99(1 + 0,014173)\ 3,95368\ x\ 0,78215(1 - 0,86583)$$

$$C_{prop} = 0,3423$$

19) Menghitung Koefisien Kerja *Compressor Core:*

$$C_c = (\gamma_c - 1)M_0[(1 + f)\frac{V_9}{a_0} - M_0 + (1 + f)\frac{R_t}{R_c}\frac{\frac{T_9}{T_0}}{\frac{V_9}{a_0}} - \frac{1 - \frac{P_0}{P_9}}{\gamma_c}$$

$dimana$:

$$\frac{T_9}{T_0} = \frac{\frac{T_{t9}}{T_0}}{\left(\frac{P_{t9}}{P_9}\right)^{(\gamma_t - 1)/\gamma_t}}$$

dan

$$\frac{T_{t9}}{T_0} = \frac{T_{t4}}{T_0}\tau_{tH}\tau_{tL}$$

$$\frac{T_{t9}}{T_0} = \frac{1733,67}{504,27}0,78215x\ 0,86583 = 2,32822$$

Maka:

$$\frac{T_9}{T_0} = \frac{2,32822}{(1,83242)^{(1,3-1)/1,3}} = 2,02454$$

Sehingga:

$$C_c = (1{,}4 - 1)0{,}242382(1 + 0{,}014173)1{,}32143 - 0{,}242382$$
$$+ (1 + 0{,}014173)\frac{49{,}56281}{53{,}35954}\frac{2{,}02454}{1{,}32143} - \frac{1 - 1{,}79062}{1{,}4}$$

$$C_c = 0{,}02741$$

20) Menghitung koefisien kerja *output* pada *engine core total:*

$$C_{tot} = C_{prop} + C_c$$
$$C_{tot} = 0{,}3423 + 0{,}02741$$
$$C_{tot} = 0{,}36971$$

21) Menghitung *Thrust and Mass Flow Ratio*:

$$\frac{F}{\dot{m}_0} = \frac{C_{tot}C_{pc}T_0}{V_0}$$
$$\frac{F}{\dot{m}_0} = \frac{0{,}36971\ x\ 0{,}24\ x\ 504{,}27}{266{,}8418}$$
$$\frac{F}{\dot{m}_0} = 220{,}20857\ lbf/(lbm/sec)$$

22) Menghitung *Specific Fuel Consumption:*

$$S = \frac{f}{F/\dot{m}_0}$$
$$S = \frac{0{,}014173\ x\ 3600}{220{,}20857} = 0{,}23169\ (lbm/hr)/lbf$$

23) Menghitung *Specific Power*:

$$\frac{\dot{W}}{\dot{m}_0} = C_{tot}C_{pc}T_0$$
$$\frac{\dot{W}}{\dot{m}_0} = 0{,}36971\ x\ 0{,}24\ x\ 504{,}27$$
$$\frac{\dot{W}}{\dot{m}_0} = 44{,}74437\ hp/(lbm/sec)$$

24) Menghitung *Efficiency Thermal*, *Propulsive*, *Overall*

$$\eta T = \frac{0,36971}{\frac{0,014173\ x\ 18.400}{0,276x\ 504,27}} = 17,2\%$$

$$\eta P = \frac{0,36971}{\left(\frac{0,3423}{0,83}\right) + \left(\frac{1,4-1}{2}\right) x\ (1 + 0,014173) x\ [(1,32143)^2 - 0,242382^2]}$$

$$\eta P = 49\%$$

$$\eta O = 17,2\%\ x\ 49\% = 8,4\%$$

20. Perhitungan *performance* setelah *TBO Extension* (5.600 *hours*) pada ketinggian 13.500 ft berdasarkan data *Aircraft Flight Log (AFL)*. Tabel 1.21 merupakan parameter *input engine TBO extension* 5.600 *hours*.

Tabel 1.21 Parameter *Input Engine TBO* 3600 *hours*

Parameter	*Input*	Satuan
T_0	502,47	^0R
Tt_4	1733,67	^0R

Perhitungan:

1) Menghitung konstanta gas di kompresor:

$$R_c = \frac{\gamma_c - 1}{\gamma_c} C_{pc}$$

$$R_c = \frac{1,4 - 1}{1,4} 0,24$$

$$R_c = 0,06857\ BTU/lbm.°R$$

$$R_c = 0,06857\ x\ 778,16\ ft.lbf/lbm.°R$$

$$R_c = 53,35954\ ft.lbf/lbm.°R$$

2) Menghitung konstanta gas di t*urbine*:

$$R_t = \frac{\gamma_t - 1}{\gamma_t} C_{pt}$$

$R_t = \frac{1,3-1}{1,3} 0,276 \ = 0,63692$ *BTU/lbm.°R*

$R_t = 0,63692 \ x \ 778,16 \ \ ft.lbf/bm.°R$

$R_t = 49,56281 \ \ ft.lbf/bm.°R$

3) Menghitung *Sound Speed* atau kecepatan suara:

$a_0 = \sqrt{\gamma_c \ R_c \ \ g_c \ T_0}$

$a_0 = \sqrt{1,4 \text{ x } \ 53,35954 \ x \ 32,174 \ x \ 502,47}$

$a_0 = 1.098,94932 ft/sec$

4) Menghitung *Absolute velocity*:

V_0= TAS=$(\frac{FL}{1.000} x \ 2\% \ x \ 0,98 \ x \ IAS) + IAS$

V_0= $(\frac{13500}{1000} x \ 2\% \ x \ 0,98 \ x \ 125) + 125$

V_0= $158,072 knot$

V_0= $158,072 NM/hr$

V_0= $158,072 x \ 1,852 \ km/hr$

V_0= $292,755 \ km/hr$

V_0= $82,321 \ m/sec$

V_0= $\ 81,321 x \ 3,2808 = 266,7742 \ ft/sec$

5) Menghitung $Ratio \ Temperature \ Ram$:

$\tau_r = 1 + \frac{\gamma_c - 1}{2} M_0^2$

$dimana$:

$M_0 = V_0/a_0$

$M_0 = \frac{266,7742}{1.098,94932} = 0,242754 Mach$

$\tau_r = 1 + \frac{1,4 - 1}{2} 0,242754^2$

$\tau_r = 1,01179$

6) Menghitung $Ram\ Pressure\ Ratio$:

$$\pi_r = \tau_r{}^{\gamma_c/\,(\gamma_c-1)}$$

$$\pi_r = 1{,}01179^{1{,}4/\,(1{,}4-1)} = 1{,}04186$$

7) Menghitung *Inlet Pressure Ratio:*

$$\pi_d = \pi_{dmax}\ x\ \eta_r$$

Dimana:

η_r= 1 untuk $M_0 \leq 1$

$\eta_r = 1 - 0{,}0075(M_0 - 1)^{1{,}35}$ untuk $M_0 \geq 1$

$$\pi_d = 0{,}97\ x\ 1 = 0{,}97$$

8) Menghitung *entalphy ratio* di ruang bakar dengan *ambient temperature* pada ketinggian terbang:

$$\tau_\lambda = \frac{C_{pt}\ x\ T_{t4}}{C_{pc}T_0}$$

$$\tau_\lambda = \frac{0{,}276\ x 1733{,}67}{0{,}24\ x\ 502{,}47} = 3{,}96692$$

9) Menghitung *temperature ratio* di ruang bakar dengan *ambient temperature* pada ketinggian terbang :

$$\tau_c = \pi_c{}^{(\gamma_c-1)/\,(\gamma_c\ \varepsilon_c)}$$

$$\tau_c = 7^{(1{,}4-1)/\,(1{,}4\ x\ 0{,}90)} = 1{,}85475$$

10) Menghitung *Compressor Efficiency*:

$$\eta_c = \frac{\pi_c{}^{(\gamma_c-1)/\gamma_c} - 1}{\tau_c - 1}$$

$$\eta_c = \frac{7^{(1{,}4-1)/1{,}4} - 1}{1{,}85475 - 1} = 0{,}87001$$

11) Menghitung *Fuel/Air Ratio:*

$$f = \frac{\tau_\lambda - \tau_r\tau_c}{\eta_b h_{PR}/(C_{pc}T_0) - \tau_\lambda}$$

$$f = \frac{3{,}96692 - 1{,}01179\ x\ 1{,}85475}{0{,}99\ x\ 18.400/(0{,}24\ x\ 502{,}47) - 3{,}96692} = 0{,}014211$$

12) Menghitung *High Temperature Turbine*:

$$\tau_{tH} = 1 - \frac{\tau_r(\tau_c - 1)}{\eta_{mH}(1 + f)\tau_\lambda}$$

$$\tau_{tH} = 1 - \frac{1{,}01179\ \ (1{,}85475 - 1)}{0{,}99(1 + 0{,}014211)3{,}96692} = 0{,}78288$$

13) Menghitung *Turbine High Temperature Ratio*:

$$\pi_{tH} = \ \tau_{tH}^{\gamma_t/[(\gamma_t-1)e_{tH}]}$$

$$\pi_{tH} = \ 0{,}78288^{\frac{1{,}3}{(1{,}3-1)0{,}89}} = 0{,}30367$$

14) Menghitung *Turbine Low Temperature Ratio*:

$$\tau_{tLi}^{*} = \frac{\tau_{tH}^{-1/e_{tH}}}{\pi} + A$$

Dimana

$$\pi = (\pi_r\pi_d\pi_c\pi_b\pi_n)^{(\gamma_t-1)/\,\gamma_t}$$

dan

$$A = \frac{\left[\frac{\gamma_c - 1}{2}\right]\left[\frac{M_0^2}{(\tau_\lambda\,\tau_{tH})}\right]}{(\eta_{prop}\eta_g\eta_{mL})^2}$$

$maka$:

$$\pi = (1{,}04186\ x\ 0{,}97\ x\ 7\ x\ 0{,}96\ x\ 0{,}99)^{(1{,}3-1)/\,1{,}3} = 1{,}55232$$

dan

$$A = \frac{\left[\frac{1{,}4 - 1}{2}\right]\left[\frac{0{,}242754^2}{(3{,}96692\ x\ 0{,}78288)}\right]}{(0{,}83x\ 0{,}99\ x\ 0{,}99)^2} = 3{,}8x\ 10^{-3}$$

Selanjutnya nilai τ_{tLi}^{*} dilakukan iterasi sampai nilainya mendekati 0,0001.

$$\tau_{tLi}^{*} = \frac{0{,}78288^{-1/0{,}89}}{1{,}55232} + 3{,}8x\ 10^{-3} = 0{,}85193$$

$$\tau_{tLx} = \frac{\tau_{tH}^{-1/e_{tH}}}{\pi} \tau_{tLi}^{-(1-e_{tL})/e_{tL}} + A(1 + \frac{1-e_{tL}}{e_{tL}} \frac{\tau_{tH}^{-1/e_{tH}} \ \tau_{tLi}^{-1/e_{tL}}}{\pi})^2$$

$$\tau_{tLx} = \frac{0{,}78288^{-1/0{,}89}}{1{,}55232} 0{,}85193^{-(1/0{,}91)/0{,}91} +$$

$$3{,}8x\ 10^{-3}(1 + \frac{1-0{,}91}{0{,}91} \frac{0{,}78288^{-1/0{,}89} x\ 0{,}85193^{-1/0{,}91}}{1{,}55232})^2$$

$$\tau_{tLx} = 0{,}866277$$

$$\tau_{tLxx} = \frac{\tau_{tH}^{-1/e_{tH}}}{\pi} \tau_{tLx}^{-(1-e_{tL})/e_{tL}} + A(1 + \frac{1-e_{tL}}{e_{tL}} \frac{\tau_{tH}^{-1/e_{tH}} \ \tau_{tLx}^{-1/e_{tL}}}{\pi})^2$$

$$\tau_{tLxx} = \frac{0{,}78288^{-1/0{,}89}}{1{,}55232} 0{,}866277^{-(1/0{,}91)/0{,}91} +$$

$$3{,}8x\ 10^{-3}(1 + \frac{1-0{,}91}{0{,}91} \frac{0{,}78288^{-1/0{,}89} x\ 0{,}866277^{-1/0{,}91}}{1{,}55232})^2$$

$$\tau_{tLxx} = 0{,}86484$$

$$\tau_{tLxxx} = \frac{\tau_{tH}^{-1/e_{tH}}}{\pi} \tau_{tLxx}^{-(1-e_{tL})/e_{tL}} + A(1 + \frac{1-e_{tL}}{e_{tL}} \frac{\tau_{tH}^{-1/e_{tH}} \ \tau_{tLxx}^{-1/e_{tL}}}{\pi})^2$$

$$\tau_{tLxxx} = \frac{0{,}78288^{-1/0{,}89}}{1{,}55232} 0{,}86484^{-(1/0{,}91)/0{,}91} +$$

$$3{,}8x\ 10^{-3}(1 + \frac{1-0{,}91}{0{,}91} \frac{0{,}78288^{-1/0{,}89} x\ 0{,}86484^{-1/0{,}91}}{1{,}55232})^2$$

$$\tau_{tLxxx} = 0{,}86498$$

$\tau_{tLxxx} - \tau_{tLxx} = 0{,}86498 - 0{,}86484 = 0{,}00014$ telah terpenuhi iterasi.

Sehingga nilai *Turbine Low Temperature Ratio* (τ_{tLi}^{*}) sebesar 0,86498

15) Menghitung *Turbine Low Pressure Ratio*:

$$\pi_{tL} = \tau_{tL}^{\frac{\gamma_t}{\gamma_t - 1 e_{tL}}}$$

$$\pi_{tL} = 0{,}86498^{\frac{1{,}3}{(1{,}3-1)0{,}91}} = 0{,}50123$$

16) Menghitung *Ratio Total Pressure dan Overall Pressure*:

$$\frac{P_{t9}}{P_0} = \pi_r \pi_d \pi_c \pi_b \pi_{tH} \pi_{tL} \pi_n$$

$$\frac{P_{t9}}{P_0} = 1{,}04186 x\ 0{,}97\ x\ 7\ x\ 0{,}96\ x\ 0{,}30367\ x\ 0{,}50123 x\ 0{,}99$$

$$\frac{P_{t9}}{P_0} = 1{,}02334$$

17) Menghitung rasio kecepatan aliran udara di *nozzle* dan *Sound Speed*:

$$\frac{V_9}{a_0} = \sqrt{\frac{2\tau_\lambda \tau_{tH} \tau_{tL}}{\gamma_c - 1}[1 - \left(\frac{P_{t9}}{P_9}\right)^{-(\gamma_t - 1)/\gamma_t}]}$$

$dimana$:

$$\frac{P_{t9}}{P_9} = \left(\frac{\gamma_t + 1}{2}\right)^{\gamma_{t/(\gamma_t - 1)}}$$

Maka:

$$\frac{P_{t9}}{P_9} = \left(\frac{1{,}3 + 1}{2}\right)^{1{,}3/(1{,}3-1)} = 1{,}83242$$

$$\frac{P_0}{P_9} = \frac{\frac{P_{t9}}{P_9}}{\frac{P_{t9}}{P_0}} = \frac{1{,}83242}{1{,}02334} = 1{,}79063$$

Sehingga:

$$\frac{V_9}{a_0} = \sqrt{\frac{2\ x\ 3{,}96692\ x\ 0{,}78288\ x\ 0{,}86498}{1{,}4 - 1}[1 - (1{,}83242)^{-(1{,}3-1)/1{,}3}]}$$

$$\frac{V_9}{a_0} = 1{,}32361$$

18) Menghitung Koefisien Kerja *Output Propeller*:

$$C_{prop} = \eta_{prop} \eta_g \eta_{mL} (1 + f) \tau_\lambda \tau_{tH} (1 - \tau_{tL})$$

$$C_{prop} = 0{,}83 x\ 0{,}99\ x\ 0{,}99(1 + 0{,}014211)\ 3{,}96692\ x\ 0{,}78288(1 - 0{,}86498)$$

$$C_{prop} = 0{,}34595$$

19) Menghitung Koefisien Kerja *Compressor Core:*

$$C_c = (\gamma_c - 1)M_0[(1+f)\frac{V_9}{a_0} - M_0 + (1+f)\frac{R_t}{R_c}\frac{\frac{T_9}{T_0}}{\frac{V_9}{a_0}} - \frac{1-\frac{P_0}{P_9}}{\gamma_c}$$

$dimana$:

$$\frac{T_9}{T_0} = \frac{\frac{T_{t9}}{T_0}}{\left(\frac{P_{t9}}{P_9}\right)^{(\gamma_t-1)/\gamma_t}}$$

dan

$$\frac{T_{t9}}{T_0} = \frac{T_{t4}}{T_0}\tau_{tH}\tau_{tL}$$

$$\frac{T_{t9}}{T_0} = \frac{1733,67}{502,47}0,78288x\ 0,86498 = 2,33591$$

Maka:

$$\frac{T_9}{T_0} = \frac{2,33591}{(1,83242)^{(1,3-1)/1,3}} = 2,03122$$

Sehingga:

$$C_c = (1,4-1)0,242754(1+0,014211)1,32361 - 0,242754 + (1+0,014211)\frac{49,56281}{53,35954}\frac{2,03122}{1,32361} - \frac{1-1,79063}{1,4}$$

$$C_c = 0,0275$$

20) Menghitung koefisien kerja *output* pada *engine core total:*

$$C_{tot} = C_{prop} + C_c$$

$$C_{tot} = 0,34595 + 0,0275$$

$$C_{tot} = 0,37345$$

21) Menghitung *Thrust and Mass Flow Ratio*:

$$\frac{F}{\dot{m}_0} = \frac{C_{tot}C_{pc}T_0}{V_0}$$

$$\frac{F}{\dot{m}_0} = \frac{0,37345\ x\ 0,24\ x\ 502,47}{266,7742}$$

$$\frac{F}{\dot{m}_0} = 221{,}69895\ lbf/(lbm/sec)$$

22) Menghitung *Specific Fuel Consumption:*

$$S = \frac{f}{F/_{\dot{m}_0}}$$

$$S = \frac{0{,}014211\ x\ 3600}{221{,}69895} = 0{,}23077\ (lbm/hr)/lbf$$

23) Menghitung *Specific Power*:

$$\frac{\dot{W}}{\dot{m}_0} = C_{tot}C_{pc}T_0$$

$$\frac{\dot{W}}{\dot{m}_0} = 0{,}37345\ x\ 0{,}24\ x\ 502{,}47$$

$$\frac{\dot{W}}{\dot{m}_0} = 45{,}0358\ hp/(lbm/sec)$$

24) Menghitung *Efficiency Thermal*, *Propulsive*, *Overall*

$$\eta T = \frac{0{,}37345}{\frac{0{,}014211\ x\ 18.400}{0{,}276x\ 502{,}47}} = 17{,}2\%$$

$$\eta P = \frac{0{,}37345}{\left(\frac{0{,}34595}{0{,}83}\right) + \left(\frac{1{,}4-1}{2}\right) x\ (1 + 0{,}014211) x\ [(1{,}32361)^2 - 0{,}242754^2]}$$

$$\eta P = 49{,}1\%$$

$$\eta O = 17{,}2\%\ x\ 49{,}1\% = 8{,}4\%$$