

```

1: "CALCULO DE TURBINA"
2: "Estado 3"
3: T3=600
4: P3=2,624
5: h3=Enthalpy(Air_ha;T=T3;P=P3)
6: s3=Entropy(Air_ha;T=T3;P=P3)
7: v3=Volume(Air_ha;T=T3;P=P3)
8:
9: "ESTADO 4"
10: P4=0,9066
11: s4=s3
12: h4=Enthalpy(Air_ha;s=s4;P=P4)
13: v4=Volume(Air_ha;s=s4;P=P4)
14:
15: n=160000 "RPM"
16: sigma=0,5 "Grado de reaccion"
17: m_dot=0,1522 "Flujo masico de la mezcla"
18: G_dot=0,1663
19:
20: "Salto entalpico total en la turbina"
21: Ys=h3-h4
22:
23: "Velocidad teorica adquirida"
24: C_s=sqrt(2*Ys*10^3)
25:
26: "consumo de gas"
27: m_dot=Pa/(Ys*eta_total)
28:
29: eta_total=eta_i*eta_m
30:
31: eta_m=0,98 "eficiencia mecanica supuesta"
32: eta_i=0,70 "Rendimiento interno supuesto"
33:
34: nq=333*n/60*Q_dot^(1/2)*(Ys*10^3)^(-3/4) "numero especifico de revoluciones"
35: Q_dot=m_dot*(v3+v4)/2
36: "Coeficiente de velocidad periferica"
37: {u_o/C_s=0,47*(1+0,8*sigma)}
38: u_o/C_s=0,38*(1+0,8*sigma)
39:
40: "Diametro medio de rodete"
41: dm=(u_o*60)/(pi*n)
42:
43: "Seleccion de angulo de tobera"
44: alpha_1=18
45: {alpha_1=beta_2} "revisaaaaaar"
46:
47: kf=0,95
48:
49: "Càlculo triangulo de velocidades"
50: "Triàngulo de entrada"
51: c1=kf*C_s
52:
53: c_1a=c1*sin(alpha_1)
54: c_1u=c1*cos(alpha_1)
55:
56: w1=sqrt(u_o^2+c1^2-2*u_o*c1*cos(alpha_1))
57:
58: beta_1=arctan(c_1a/(u_o-c_1u))
59:
60: "Triàngulo de salida"
61: beta_2=180-(180+beta_1)

```

62:
63: *"Ángulo de desviación"*
64: THETA=(180+beta_1)-beta_2
65: k`m=0,89 *"Tomado del libro de Claudio Mataix (figura 6,7)"*
66: km=0,76 *"Con el objetivo de que los alabes sean mas cortos desminuimos el valor k`m en 10 a 15%"*
67: w2=km*w1
68: c2=sqrt(u_o^2+w2^2-2*u_o*w2*cos(beta_2))
69: c_2a=w_2a
70: w_2a=w2*sin(beta_2)
71: c_2u=u_o-w_2u
72: w_2u=w2*cos(beta_2)
73: alpha_2=arctan(c_2a/(c_2u))
74:
75: *"Perdidas en las toberas"*
76: y1=((C_s^2-c1^2)/2)/1000
77: y11=((1-kf^2)*C_s^2/2)/1000
78:
79: *"Perdidas en los albes"*
80: y2=((w1^2-w2^2)/2)/1000
81:
82: *"Estado termodinamico a la salida de las toberas"*
83: h1=h4+y1
84: v1=Volume(Air_ha;P=P3;h=h1)
85: *"Estado termodinamico a la salida de los alabes"*
86: h2=h1+y2
87: v2=Volume(Air_ha;P=P3;h=h2)
88: *"Altura de las toberas a la salida para admision total"*
89: tau_1=0,91
90: l_tob_at=(m_dot*v1)/(pi*dm*c_1a*tau_1)
91: l_tob=8
92: epsilon=l_tob_at*10^3/l_tob
93: *"altura de los alabes a entrada"*
94: l1=l_tob+5*dm*10^3/1000
95: *"altura de los albes del rodete a la salida"*
96: l2=(m_dot*v2)/(epsilon*pi*dm*c_2a*tau_1)
97:
98: *"Perdidas en por velocidad"*
99: y3=(c2^2/2)/1000
100:
101: *"estado del gas despues de la conversion de energia cinetica en entalpia"*
102: hj=h2+y3
103: vj=Volume(Air_ha;P=P3;h=hj)
104:
105: *"Salto periferico"*
106: Yu=Ys-y1-y2-y3
107: *"Rendimiento periferico"*
108: eta_u=Yu/Ys
109: *"Potencia perdida por rozamiento"*
110: Nr=0,0095*rho*(n/60)^3*(dm)^5
111: rho=1/v4
112:
113:
114: *"perdida de salto entalpico"*
115: y5=(Nr/m_dot)/1000
116: Yi=Yu-y5
117: eta_j=Yi/Ys
118:
119: *"rendimiento corregido"*
120: m_dot=Pa_real/(Ys*eta_total_real)
121:

$$122: \text{eta_total_real} = \text{eta_i} * \text{eta_m}$$

123:

124:

125: *"Par transmitido por el eje"*

$$126: M_o = (P_a_real * 60 * 10^{**3}) / (2 * \pi * n)$$

127: *"Diametro del eje segun formula de torsion"*

$$128: d_e = ((16 * M_o) / (\pi * \tau))^{** (1/3)}$$

$$129: \tau = 19,6 * 10^{**6} \text{ *"Para el eje adoptaremos un esfuerzo maximo admisible de 19,6 MN/m**2"*}$$

CALCULO DE TURBINA

Estado 3

$$T_3 = 600$$

$$P_3 = 2,624$$

$$h_3 = h [\text{Air}_{ha} ; T = T_3 ; P = P_3]$$

$$s_3 = s [\text{Air}_{ha} ; T = T_3 ; P = P_3]$$

$$v_3 = v [\text{Air}_{ha} ; T = T_3 ; P = P_3]$$

ESTADO 4

$$P_4 = 0,9066$$

$$s_4 = s_3$$

$$h_4 = h [\text{Air}_{ha} ; s = s_4 ; P = P_4]$$

$$v_4 = v [\text{Air}_{ha} ; s = s_4 ; P = P_4]$$

$$n = 160000 \text{ *RPM*}$$

$$\sigma = 0,5 \text{ *Grado de reaccion*}$$

$$\dot{m} = 0,1522 \text{ *Flujo masico de la mezcla*}$$

$$\dot{G} = 0,1663$$

Salto entalpico total en la turbina

$$Y_s = h_3 - h_4$$

Velocidad teorica adquirida

$$C_s = \sqrt{2 \cdot Y_s \cdot 10^3}$$

consumo de gas

$$\dot{m} = \frac{P_a}{Y_s \cdot \eta_{total}}$$

$$\eta_{total} = \eta_i \cdot \eta_m$$

$$\eta_m = 0,98 \text{ *eficiencia mecanica supuesta*}$$

$$\eta_i = 0,7 \text{ *Rendimiento interno supuesto*}$$

$$n_q = 333 \cdot \frac{n}{60} \cdot \dot{Q} \left[\frac{1}{2} \right] \cdot [Y_s \cdot 10^3] \left[\frac{-3}{4} \right] \text{ numero especifico de revoluciones}$$

$$\dot{Q} = \dot{m} \cdot \left[\frac{v_3^2 + v_4^2}{2} \right]$$

Coeficiente de velocidad periferica

$$\frac{u_o}{C_s} = 0,38 \cdot [1 + 0,8 \cdot \sigma]$$

Diametro medio de rodete

$$d_m = \frac{u_o \cdot 60}{\pi \cdot n}$$

Seleccion de angulo de tobera

$$\alpha_1 = 18$$

revisaaaaaar

$$k_f = 0,95$$

Càlculo triangulo de velocidades

Triàngulo de entrada

$$c_1 = k_f \cdot C_s$$

$$c_{1a} = c_1 \cdot \sin [\alpha_1]$$

$$c_{1u} = c_1 \cdot \cos [\alpha_1]$$

$$w_1 = \sqrt{u_o^2 + c_1^2 - 2 \cdot u_o \cdot c_1 \cdot \cos [\alpha_1]}$$

$$\beta_1 = \arctan \left[\frac{c_{1a}}{u_o - c_{1u}} \right]$$

Triàngulo de salida

$$\beta_2 = 180 - [180 + \beta_1]$$

Àngulo de desviacion

$$\Theta = 180 + \beta_1 - \beta_2$$

$$k'm = 0,89 \text{ Tomado del libro de Claudio Mataix (figura 6,7)}$$

$$k_m = 0,76$$

Con el objetivo de que los alabes sean mas cortos desminuimos el valor k`m en 10 a 15%

$$w_2 = k_m \cdot w_1$$

$$c_2 = \sqrt{u_o^2 + w_2^2 - 2 \cdot u_o \cdot w_2 \cdot \cos [\beta_2]}$$

$$C_{2a} = W_{2a}$$

$$W_{2a} = W_2 \cdot \sin [\beta_2]$$

$$C_{2u} = U_o - W_{2u}$$

$$W_{2u} = W_2 \cdot \cos [\beta_2]$$

$$\alpha_2 = \arctan \left[\frac{C_{2a}}{C_{2u}} \right]$$

Perdidas en las toberas

$$y_1 = \frac{C_s^2 - c_1^2}{2 \cdot 1000}$$

$$y_{11} = \frac{[1 - k_f^2] \cdot \frac{C_s^2}{2}}{1000}$$

Perdidas en los albes

$$y_2 = \frac{W_1^2 - W_2^2}{2 \cdot 1000}$$

Estado termodinámico a la salida de las toberas

$$h_1 = h_4 + y_1$$

$$v_1 = v [Air_{ha} ; P = P_3 ; h = h_1]$$

Estado termodinámico a la salida de los albes

$$h_2 = h_1 + y_2$$

$$v_2 = v [Air_{ha} ; P = P_3 ; h = h_2]$$

Altura de las toberas a la salida para admisión total

$$\tau_1 = 0,91$$

$$l_{tob;at} = \frac{\dot{m} \cdot v_1}{\pi \cdot dm \cdot C_{1a} \cdot \tau_1}$$

$$l_{tob} = 8$$

$$\varepsilon = l_{tob;at} \cdot \frac{10^3}{l_{tob}}$$

altura de los albes a entrada

$$l_1 = l_{tob} + 5 \cdot dm \cdot \frac{10^3}{1000}$$

altura de los albes del rodete a la salida

$$l_2 = \frac{\dot{m} \cdot v_2}{\varepsilon \cdot \pi \cdot dm \cdot C_{2a} \cdot \tau_1}$$

Perdidas en por velocidad

$$y_3 = \frac{c_2^2}{2 \cdot 1000}$$

estado del gas despues de la conversion de energia cinetica en entalpia

$$h_j = h_2 + y_3$$

$$v_j = v \left[\text{Air}_{\text{na}} ; P = P_3 ; h = h_j \right]$$

Salto periferico

$$Y_u = Y_s - y_1 - y_2 - y_3$$

Rendimiento periferico

$$\eta_u = \frac{Y_u}{Y_s}$$

Potencia perdiada por rozamiento

$$N_r = 0,0095 \cdot \rho \cdot \left[\frac{n}{60} \right]^3 \cdot d_m^5$$

$$\rho = \frac{1}{v_4}$$

perdida de salto entalpico

$$y_5 = \frac{N_r}{\dot{m} \cdot 1000}$$

$$Y_i = Y_u - y_5$$

$$\eta_i = \frac{Y_i}{Y_s}$$

rendimiento corregido

$$\dot{m} = \frac{P_{a_{\text{real}}}}{Y_s \cdot \eta_{\text{total;real}}}$$

$$\eta_{\text{total;real}} = \eta_i \cdot \eta_m$$

Par transmitido por el eje

$$M_o = \frac{P_{a_{\text{real}}} \cdot 60 \cdot 10^3}{2 \cdot \pi \cdot n}$$

Diametro del eje segun formula de torsion

$$d_e = \left[\frac{16 \cdot M_o}{\pi \cdot \tau} \right]^{1/3}$$

$$\tau = 19,6 \cdot 10^6 \quad \text{Para el eje adoptaremos un esfuerzo maximo admisible de } 19,6 \text{ MN/m}^{**2}$$

SOLUTION

Unit Settings: SI C bar kJ mass deg

$\alpha^1 = 18$	$\alpha^2 = 41,79$ [deg]	$\beta^1 = -38,32$ [deg]
$\beta^2 = 38,32$	$c^1 = 648,2$	$c^2 = 228,4$
$c^{1a} = 200,3$	$c^{1u} = 616,4$	$c^{2a} = 152,2$
$c^{2u} = 170,3$	$C_s = 682,3$	de = 0,007207
$dm = 0,04333$	$\varepsilon = 0,572$	$\eta^i = 0,6953$
$\eta^m = 0,98$	$\eta^{total} = 0,686$	$\eta^{total,real} = 0,6814$
$\eta^u = 0,6957$	$\eta^l = 0,7$	$\dot{G} = 0,1663$
$h^1 = 693,5$	$h^2 = 715,6$	$h^3 = 903,6$
$h^4 = 670,9$	$h_j = 741,7$	$k_f = 0,95$
$km = 0,76$	$k^*m = 0,89$	$l^1 = 8,217$ [mm]
$l^2 = 0,01084$ [m]	$l_{tob} = 8$ [mm]	$l_{tob,at} = 0,004576$ [mm]
$\dot{m} = 0,1522$	$M_o = 1,441$	$n = 160000$
$nq = 40,35$	$N_r = 13,16$	$P^3 = 2,624$
$P^4 = 0,9066$	Pa = 24,3	Pa_{real} = 24,14
$\dot{Q} = 0,2319$	$\rho = 0,4784$	$s^3 = 7,707$
$s^4 = 7,707$	$\sigma = 0,5$	$T^3 = 600$
$\tau = 1,960E+07$	$\tau^1 = 0,91$	$\Theta = 103,4$
$u_o = 363$	$v^1 = 0,746$	$v^2 = 0,7684$
$v^3 = 0,9562$	$v^4 = 2,09$	$v_j = 0,7949$
$w^1 = 323,1$	$w^2 = 245,5$	$w^{2a} = 152,2$
$w^{2u} = 192,6$	$y^1 = 22,69$	$y^{11} = 22,69$
$y^2 = 22,04$	$y^3 = 26,09$	$y^5 = 0,08645$
$Y^i = 161,8$	$Y_s = 232,8$	$Y_u = 161,9$

19 potential unit problems were detected.

EES suggested units (shown in purple) for alpha_2 beta_1 .

There are a total of 69 equations in the Main program.

Block	Rel. Res.	Abs. Res.	Units	Calls	Time(ms)	Equations
0	0.000E+00	0.000E+00	OK	1	0	T³=600
0	0.000E+00	0.000E+00	OK	1	0	P³=2,624
0	0.000E+00	0.000E+00	OK	1	0	P⁴=0,9066
0	0.000E+00	0.000E+00	OK	1	0	n=160000
0	0.000E+00	0.000E+00	OK	1	0	sigma=0,5
0	0.000E+00	0.000E+00	OK	1	0	m_dot=0,1522
0	0.000E+00	0.000E+00	OK	1	0	G_dot=0,1663
0	0.000E+00	0.000E+00	OK	1	0	eta_m=0,98
0	0.000E+00	0.000E+00	OK	1	0	eta_i=0,70
0	0.000E+00	0.000E+00	OK	1	0	alpha_1=18
0	0.000E+00	0.000E+00	OK	1	0	k_f=0,95
0	0.000E+00	0.000E+00	OK	1	0	k^*m=0,89
0	0.000E+00	0.000E+00	OK	1	0	km=0,76
0	0.000E+00	0.000E+00	OK	1	0	tau_1=0,91
0	0.000E+00	0.000E+00	OK	1	0	l_tob=8
0	0.000E+00	0.000E+00	?	4	0	h³=Enthalpy(Air_ha;T=T³;P=P³)
0	0.000E+00	0.000E+00	?	4	0	s³=Entropy(Air_ha;T=T³;P=P³)
0	0.000E+00	0.000E+00	?	4	0	v³=Volume(Air_ha;T=T³;P=P³)
0	0.000E+00	0.000E+00	OK	4	0	s⁴=s³
0	0.000E+00	0.000E+00	?	4	0	h⁴=Enthalpy(Air_ha;s=s⁴;P=P⁴)
0	0.000E+00	0.000E+00	?	4	16	v⁴=Volume(Air_ha;s=s⁴;P=P⁴)
0	0.000E+00	0.000E+00	OK	4	0	Y_s=h³-h⁴
0	0.000E+00	0.000E+00	OK	4	0	C_s=sqrt(2*Y_s*10^3)
0	0.000E+00	0.000E+00	OK	4	0	Q_dot=m_dot*(v³+v⁴)/2
0	1,019E-19	5,421E-20	OK	4	0	u_o/C_s=0,38*(1+0,8*sigma)
0	0.000E+00	0.000E+00	OK	4	0	dm=(u_o*60)/(pi*n)
0	0.000E+00	0.000E+00	OK	4	0	c¹=k_f*C_s

0	0.000E+00	0.000E+00	?	4	0	c_1a =c1*sin(alpha_1)
0	0.000E+00	0.000E+00	?	4	0	c_1u =c1*cos(alpha_1)
0	0.000E+00	0.000E+00	?	4	0	w1 =sqrt(u_o^2+c1^2-2*u_o*c1*cos(alpha_1))
0	0.000E+00	0.000E+00	OK	4	0	beta_1 =arctan(c_1a/(u_o-c_1u))
0	0.000E+00	0.000E+00	?	4	0	beta_2 =180-(180+beta_1)
0	0.000E+00	0.000E+00	?	4	0	THETA =(180+beta_1)-beta_2
0	0.000E+00	0.000E+00	OK	4	0	w2 =km*w1
0	0.000E+00	0.000E+00	?	4	0	c2 =sqrt(u_o^2+w2^2-2*u_o*w2*cos(beta_2))
0	0.000E+00	0.000E+00	?	4	0	w_2a =w2*sin(beta_2)
0	0.000E+00	0.000E+00	?	4	0	w_2u =w2*cos(beta_2)
0	0.000E+00	0.000E+00	OK	4	0	y1 =((C_s^2-c1^2)/2)/1000
0	0.000E+00	0.000E+00	OK	4	0	y11 =((1-kf^2)*C_s^2/2)/1000
0	0.000E+00	0.000E+00	OK	4	0	y2 =(w1^2-w2^2)/2/1000
0	0.000E+00	0.000E+00	OK	4	0	h1 =h4+y1
0	0.000E+00	0.000E+00	?	4	0	v1 =Volume(Air_ha;P=P3;h=h1)
0	0.000E+00	0.000E+00	OK	4	0	h2 =h1+y2
0	0.000E+00	0.000E+00	?	4	0	v2 =Volume(Air_ha;P=P3;h=h2)
0	0.000E+00	0.000E+00	?	4	0	l_tob_at =(m_dot*v1)/(pi*dm*c_1a*tau_1)
0	0.000E+00	0.000E+00	OK	4	0	epsilon =l_tob_at*10^3/l_tob
0	0.000E+00	0.000E+00	?	4	0	l1 =l_tob+5*dm*10^3/1000
0	0.000E+00	0.000E+00	OK	4	0	y3 =(c2^2/2)/1000
0	0.000E+00	0.000E+00	OK	4	0	hj =h2+y3
0	0.000E+00	0.000E+00	?	4	0	vj =Volume(Air_ha;P=P3;h=hj)
0	0.000E+00	0.000E+00	OK	4	0	Yu =Ys-y1-y2-y3
0	0.000E+00	0.000E+00	OK	4	0	eta_u =Yu/Ys
0	0.000E+00	0.000E+00	OK	4	0	rho =1/v4
0	0.000E+00	0.000E+00	OK	4	0	tau =19,6*10**6
0	0.000E+00	0.000E+00	OK	4	0	eta_total =eta_i*eta_m
0	0.000E+00	0.000E+00	OK	4	0	nq =333*n/60*Q_dot^(1/2)*(Ys*10^3)^(-3/4)
0	0.000E+00	0.000E+00	OK	4	0	c_2a =w_2a
0	0.000E+00	0.000E+00	OK	4	0	c_2u =u_o-w_2u
0	0.000E+00	0.000E+00	OK	4	0	alpha_2 =arctan(c_2a/(c_2u))
0	0.000E+00	0.000E+00	?	4	0	l2 =(m_dot*v2)/(epsilon*pi*dm*c_2a*tau_1)
0	0.000E+00	0.000E+00	OK	4	0	Nr =0,0095*rho*(n/60)^3*(dm)^5
0	0.000E+00	0.000E+00	OK	4	0	y5 =(Nr/m_dot)/1000
0	0.000E+00	0.000E+00	OK	4	0	Yi =Yu-y5
0	0.000E+00	0.000E+00	OK	4	0	eta_i =Yi/Ys
0	0.000E+00	0.000E+00	OK	4	0	eta_total_real =eta_i*eta_m
0	0.000E+00	0.000E+00	OK	4	0	m_dot =Pa/(Ys*eta_total)
0	0.000E+00	0.000E+00	OK	4	0	m_dot =Pa_real/(Ys*eta_total_real)
0	0.000E+00	0.000E+00	OK	4	0	M_o =(Pa_real*60*10**3)/(2*pi*n)
0	0.000E+00	0.000E+00	OK	4	0	de (((16*M_o)/(pi*tau))**(1/3)