Calculating Compressor Efficiency

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Isentropic Efficiency (η)

$$\eta = \frac{T_{2i} - T_1}{T_{2a} - T_1}$$

where

T_1 = Inlet temp (CTIM)

T_{2a} = Compressor Disch. Temp (CTD)

T_{2i} = Isentropic CTD (calculated)

Isentropic Efficiency (η)

$$\eta = \frac{T_{2i} - T_1}{T_{2a} - T_1}$$

where

T_1 = Inlet temp (CTIM)

T_{2a} = Compressor Disch. Temp (CTD)

T_{2i} = Isentropic CTD (calculated)

IMPORTANT NOTE!!!!

YOU MUST USE **ABSOLUTE** VALUES FOR THE CALCULATIONS. USE RANKINE AND KELVIN INSTEAD OF FAHRENHEIT AND CELSIUS, AND PSIA INSTEAD OF PSIG.

Calculating T_{2i}

$$T_{2i} = T_1 * \left[\frac{P_2}{P_1}\right]^{0.28571}$$

where

T_1 = Inlet temp (CTIM)

P_1 = Compressor Inlet Pressure

P_2 = Compressor Disch. Pressure (CPD)

EXAMPLE 1

Given

T_1 = 70 F (+ 460) = 530 R

T_2 = 680 F (+ 460) = 1140 R

P_1 = -0.2 psig (+ 14.7) = 14.5 psia

P_2 = 160 psig (+ 14.7) = 174.7 psia

Calculate T_{2i}

$$T_{2i} = T_1 * \left[\frac{P_2}{P_1}\right]^{0.28571}$$

$$T_{2i} = 530\ R * (174.7 / 14.5)^{0.28571}$$

$$T_{2i} = 1079.2\ R \quad (619.2\ F)$$

Isentropic Efficiency (η)

$$\eta = \frac{T_{2i} - T_1}{T_{2a} - T_1}$$

η = (1079.2 – 530) / (1140 - 530)

η = 549.2 / 610

η = 0.900 = 90.0%

EXAMPLE 2

Given

T_1 = 70 F (+ 460) = 530 R

T_2 = 687 F (+ 460) = 1147 R

P_1 = -0.2 psig (+ 14.7) = 14.5 psia

P_2 = 160 psig (+ 14.7) = 174.7 psia

Isentropic Efficiency (η)

$$\eta = \frac{T_{2i} - T_1}{T_{2a} - T_1}$$

η = (1079.2 – 530) / (1147 - 530)

η = 549.2 / 617

η = 0.8901 = 89.0%

COMPRESSOR WORK (w_c)

$$Wc = \text{mass flow} * c_p * (T_2 - T_1)$$

Mass flow = 1,000,000 lb/hr

C_p = 0.24 BTU/LB F (specific heat of air)

Divide by 3,412,141 to convert results to MW

COMPRESSOR WORK (w_c)

$$Wc = \text{mass flow} * c_p * (T_{2i} - T_1)$$

$$Wc_i = \frac{1{,}000{,}000 * 0.24 * (1079.2 - 530)}{3{,}412{,}141}$$

$Wc_i = 38.6$ MW @ 100% efficiency

COMPRESSOR WORK (w_c)

$$Wc = \text{mass flow} * c_p * (T_{2a} - T_1)$$

$$Wc_a = \frac{1{,}000{,}000 * 0.24 * (1140 - 530)}{3{,}412{,}141}$$

$Wc_a = 42.9$ MW @ 90% efficiency

COMPRESSOR WORK (w_c)

$$Wc = \text{mass flow} * c_p * (T_{2a} - T_1)$$

$$Wc_a = \frac{1{,}000{,}000 * 0.24 * (1147 - 530)}{3{,}412{,}141}$$

$Wc_a = 43.4$ MW @ 89% efficiency

90% = 42.9 MW

89% = 43.4 MW

1% → 0.5 MW

Case 1 – Clean

T1 = 70 F T2 = 680 F (619.2 F if 100%) CPD = 160 psig

Comp η = 90% Air Flow = 1,000,000 #/hr comp. work = 42.9 MW

Case 2a – Dirty

T1 = 70 F T2 = 687 F (619.2 F if 100%) CPD = 160 psig

Comp η = 89% Air Flow = 1,000,000 #/hr comp. work = 43.4 MW

Case 1 – Clean

T1 = 70 F   T2 = 680 F   (619.2 F if 100%)   CPD = 160 psig

Comp η = 90%   Air Flow = 1,000,000 #/hr   comp. work = 42.9 MW

Case 2a – Dirty

T1 = 70 F   T2 = 687 F   (619.2 F if 100%)   CPD = 160 psig

Comp η = 89%   Air Flow = 1,000,000 #/hr   comp. work = 43.4 MW

Case 2b – Dirty

T1 = 70 F   T2 = 687 F   (615.7 F if 100%)   CPD = 158 psig

Comp η = 88.4%   Air Flow = 995,000 #/hr   comp. work = 43.2 MW

From my experience,

A 1% loss in compressor efficiency actually results in a loss of generator output by about 1 MW. Half a MW loss due to the increased work required by the compressor, and another half MW loss due to reduced air flow from aerodynamic degradation.

THE MORAL OF THE STORY

Keep your compressor clean!!

QUESTIONS?