Problem Set 13 (PS13) due Monday April. 30

129 12.12 12.19 12.20

12.9

$$(a) Model: \alpha_M = 28^\circ \rightarrow M = \frac{1}{\sin \alpha_M} = 2.13$$

$$\mathrm{Re} = \frac{VL}{\nu} = \frac{LM\sqrt{rRT}}{\nu} = 93 \times 10^6$$

$$(b) Full-scale: At\ 20,000m, T = 273.15 - 56.5K = 216.65K$$

$$\rho = 8.891 \times 10^{-2} \frac{Kg}{m^{-2}}, \mu = 1.422 \times 10^{-5} N \cdot s / m^2$$

$$\therefore fullscale\ M = \frac{V}{\sqrt{rRT}} = 2.03$$

$$fullscale\ \mathrm{Re} = \frac{\rho VL}{\mu} = 113 \times 10^6$$

$$Hence, \mathrm{mod}\, el\ conditions\ close\ to\ full-scale\ performance.$$

12.12

$$(a)\frac{T_2}{T_1}=\frac{540}{290}=1.862$$

From the normal shock table, get:

$$M_1=2.206, M_2=0.546, \frac{P_2}{P_1}=5.509$$

$$\therefore V_2=M_2\sqrt{rRT_2}=255m/s$$

$$(b)\frac{P_2}{P_1}=5.509\rightarrow P_2=5.51\times 10^5\ pa=(P_2)_{shock}$$

$$Isentropic\ flow:\frac{P_2}{P_1}=\left(\frac{1+\frac{r-1}{2}M_1^2}{1+\frac{r-1}{2}M_2^2}\right)^{\frac{r}{r-1}}=8.81$$

$$\therefore (P_2)_{isentropic}=8.81\times 10^5\ pa=1.6\times (P_2)_{shock}$$

<u>12.19</u>

$$Assume\ steady, one\ \dim ensional\ flow,$$
$$isentropic\ conditions.$$

$$(a)\,\dot{m} = \rho_1 A_1 V_1 = \frac{P_1}{RT_1} A_1 M_1 \sqrt{rRT_1}$$

$$\frac{A_1}{A^*} = 3.5$$

$$\therefore M_1 = 2.80$$

$$\therefore P_1 = \frac{P_0}{(1+\frac{r-1}{2}M_1^2)^{\frac{r}{r-1}}} = 3734 Pa$$

$$and\ \ T_1 = \frac{T_0}{1+\frac{r-1}{2}M_1^2} = 114K$$

$$\therefore \dot{m} = \frac{P_1}{RT_1} A_1 M_1 \sqrt{rRT_1} = 0.120\ kg/s$$

12.19

(b) *Range of back presures*:

(1) *No shock will occur* in the nozzle when

$\mathrm{p_b} \leq p_{isentropic} = p_1$ of part (a)

(2) Strogest shock will occur when shock sits at exit from nozzle. That is $\mathrm{M_1} = 2.80$

$$From table, get \frac{P_2}{P_1} = 8.980,$$

$$P_b = P_2 = 8.98 P_1$$

$\therefore$ *Range of back presures*:

$$8.98 P_1 \geq P_b \geq P_1$$

12.20

Assume steady, one dimensional flow, isentropic conditions.

Stagnation conditions:

$$P_0 = 6.8\times10^5\,pa, T_0 = 15^\circ C = 288.15K$$

(*a*) *Maximum mass flow rate, when Mach number at throat is one* ($M^* = 1$):

$$\dot{m} = \rho^* A^* V^* = \frac{P^*}{RT^*} A^* \sqrt{rRT^*}$$

$$P^* = \frac{P_0}{(1+\frac{r-1}{2})^{\frac{r}{r-1}}} = 3.59\times10^5$$

$$T^* = \frac{T_0}{1+\frac{r-1}{2}} = 240.1K$$

$$\therefore \dot{m} = \frac{P^*}{RT^*} A^* \sqrt{rRT^*} = 4.05kg/s$$

12.20

(b) *From isentropic flow table, two solutions*

exist for $\dfrac{A_1}{A^*} = 4 : M_1 = 0.147\ \&\ M_2 = 2.94$

(c) *Back presure: fromtable,*

For $M_1 = 0.147, \dfrac{P_1}{P_0} = 0.985$

$M_2 = 2.94, \dfrac{P_1}{P_0} = 0.0298$

with $P_0 = 6.8 \times 10^5\ pa$

$P_b = 6.70 \times 10^5\ pa(subsonic\ case)$

$P_b = 0.203 \times 10^5\ pa(\sup ersonic\ case)$