UNIT VD

THRUST ENGINES

The operating principles of gas power cycles were explained in Unit VA and applied to engines that deliver their output as mechanical power. In this unit we extend these principles to engines whose output is *propulsive power*.

I. PERFORMANCE PARAMETERS FOR PROPULSION ENGINES

Like all power-producing systems, thrust engines are forward thermal engines. The thermal efficiencies of thrust engines are defined by eqn. IVB-6 and the area enclosed by the process trace on a p-v or T-s plane is their net work. Since thrust engines develop propulsion by expelling gas at high velocity, they are normally analyzed as open systems with a reference frame fixed to the engine. However, from this perspective no net work is done by the engine, that is, the net work for the cycle cannot be directly interpreted. Nevertheless, we can interpret the useful part of the engine's output as the change of kinetic energy that it produces in its flowing gases. For jet and rocket engines, resepctively, this output per unit mass of gas flow through the engine is

$$\Delta ke_j = (1 + r_{f/a})\frac{\hat{V}_e^2}{2} - \frac{\hat{V}_o^2}{2} \simeq \frac{\hat{V}_e^2}{2} - \frac{\hat{V}_o^2}{2} \qquad \Delta ke_r = \frac{\hat{V}_e^2}{2} \qquad \text{(VD-1)}$$

In these equations, $\hat{V}_e$ is the velocity of the exhaust jet relative to the engine, $\hat{V}_o$ is the speed of the air frame relative to the surrounding air, and $r_{f/a}$ is the fuel/air mass ratio.[1] Since the fuel/air ratio is usually small in jet engines, we will approximate it as zero and apply the air standard assumption. Eqn. VD-1 allows the thermal efficiency of a propulsive power engine to be written as

$$\eta_{th} = 1 - \frac{|q_L|}{|q_H|} = \frac{|\Delta ke|}{|q_H|} \qquad \text{(IVB-6)}$$

In our considerations of mechanical power - producing gas power cycles,we limited our consideration to the power generated by the working media *within* the engine. The only mechanical losses considered were viscous losses of the working media.[2] For propulsion engines not all the power generated can be used. It is demonstrated below for a jet engine and rocket engine respectively that the kinetic energy of the exhaust leaving the engine *relative to the ground,* $ke_{abs} = |\hat{V}_e - \hat{V}_o|^2/2$, does not contribute to propulsion power.

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[1]The subscript "o" refers to the free stream properties of the atmosphere.

[2]Mechanical losses such as bearing or piston ring friction occur outside the working media and are not part of the cycle traversed by the working media.