TYPE 746: VARIABLE SPEED PUMP, MASS FLOW RATE CALCULATED FROM AVAILABLE POWER, POWER DRAWN CALCULATED FROM POWER CURVE

General Description

Type746 models a pump that sets its outlet mass flow rate based upon user specified available power. It then calculates the power drawn by the pump using a power curve. Like most pumps and fans in TRNSYS, Type746 takes the inlet mass flow rate of fluid as an input but does not necessarily pass the value through to its output. Type746 sets the downstream flow. Because of the power input, this pump model is particularly useful for direct drive applications in which a pump is directly connected to an intermittent power source.

Nomenclature

$\dot{m}$	[kg/hr]	Mass flow rate of fluid passing though the pump.
$\dot{m}_{rated}$	[kg/hr]	Mass flow rate of fluid passing though the pump at rated conditions.
$\dot{P}_{available}$	[kJ/hr]	Power available to drive the pump.
$\dot{P}_{rated}$	[kJ/hr]	Power required to drive the pump at rated conditions
$\dot{P}$	[kJ/hr]	Power actually drawn by the pump.
$\dot{P}_{shaft}$	[kJ/hr]	Shaft power required by the pumping process (does not include motor inefficiency)
$a_0, a_1, a_2 \ldots$	[-]	Polynomial coefficients in the fan power curve
γ	[-]	Effective pump control signal.
Cp	[kJ/kg.K]	Specific heat of pump fluid
η_{motor}	[-]	Efficiency of the pump motor
$\eta_{overall}$	[0..1]	Overall pump efficiency (motor efficiency * pumping efficiency)
$\eta_{pumping}$	[0..1]	Efficiency of pumping the fluid
$\dot{Q}_{fluid}$	[kJ/hr]	Energy transferred from the pump motor to the fluid stream passing through the pump.
$f_{motorloss}$	[0..1]	Fraction of pump motor inefficiencies that contribute to a temperature rise in the fluid stream passing through the pump. The remainder of these inefficiencies contribute to an ambient temperature rise.
$\dot{Q}_{ambient}$	[kJ/hr]	Energy transferred from the pump motor to the ambient air surrounding the pump.
$T_{fluid,out}$	[kJ/kg]	Temperature of fluid exiting the pump
$T_{fluid,in}$	[kJ/kg]	Temperature of fluid entering the pump

Detailed Description

Type746 has three modes of operation that depend upon the input values at a given time. If the user supplies zero to the pump, the fluid outlet temperature is set to the fluid inlet temperature. Outlet mass flow rate, power drawn by the pump, energy transferred to the fluid stream and energy transferred to the pump surroundings are set to zero.

In the second mode of operation, the pump is on at its rated condition because the power available to the pump is greater than or equal to the pump's rated power. The efficiency of the pumping process is calculated by

$$\eta_{pumping} = \frac{\eta_{overall}}{\eta_{motor}} \quad \text{(Eq. 746.1)}$$

If it is not specifically listed in available data, the overall efficiency of the pump may be calculated from nameplate values using a consistent set of units as:

$$\eta_{overall} = \frac{\dot{v}_{rated}\ \Delta p_{rated}}{\dot{P}_{rated}} \quad \text{(Eq. 746.2)}$$

The pumping process efficiency is in turn used to calculate the power required by the pump shaft. The shaft power does not include the pump motor inefficiencies.

$$\dot{P}_{shaft} = \dot{P}\,\eta_{motor} \quad \text{(Eq. 746.3)}$$

The resulting outlet flow rate is equal to the specified rated mass flow rate and the energy transferred to the fluid is given by equation 746.4

$$\dot{Q}_{fluid} = \dot{P}_{shaft}\left(1-\eta_{pumping}\right)+\left(\dot{P}-\dot{P}_{shaft}\right)f_{motorloss} \quad \text{(Eq. 746.4)}$$

In equation 746.3, $\eta_{pumping}$ is the pumping process efficiency and $f_{motorloss}$ is a value between 0 and 1 that determines whether the pump motor inefficiencies cause a temperature rise in the fluid stream that passes through the pump or whether they cause a temperature rise in the ambient air surrounding the pump. Through use of the $f_{motorloss}$ fraction, the user can in effect specify whether the pump has an inline motor, in which case all waste heat would impact the fluid stream temperature and $f_{motorloss}$ would have a value of 1, or whether the pump motor is housed outside of the fluid stream such that it's waste heat impacts the ambient and $f_{motorloss}$ would have a value of 0.

The energy transferred to the ambient is given by equation 746.5

$$\dot{Q}_{ambient} = \left(\dot{P}-\dot{P}_{shaft}\right)\left(1-f_{motorloss}\right) \quad \text{(Eq. 746.5)}$$

And the outlet temperature is given by equation 746.6

$$T_{fluid,out} = T_{fluid,in} + \frac{\dot{Q}_{fluid}}{\dot{m}\ Cp} \quad \text{(Eq. 746.6)}$$

In the third operation mode, the power available to the pump is less than the pump's rated power. In this case, Type746 calculates an effective control signal by dividing the available power by the rated power. The result is a number between 0 and 1. Type746 then performs an iterative search on the generic pump power curve shown in equation 746.7 to find values of gamma and power that match the effective control signal and the available power.

$$\dot{P} = a_0 + a_1\gamma + a_2\gamma^2 + a_3\gamma^3 + \ldots \quad \text{(Eq. 746.7)}$$

With the new value of gamma, Type746 calculates the outlet flow rate using equation 746.8.

$$\dot{m} = \gamma\ \dot{m}_{rated} \quad \text{(Eq. 746.8)}$$

Energy transferred from the pump motor to the fluid stream, energy transferred from the pump motor to the ambient, and fluid outlet temperature are calculated using equations 746.1 and 746.3 through 746.5.

Type746 does not model pump starting and stopping characteristics; as soon as the pump input power changes, the outlet flow of fluid jumps to match the input power. The time constants with which pumps react to input changes are much shorter than the typical time steps used in hydronic simulations.