TYPE 741: VARIABLE SPEED PUMP, CONTROL SIGNAL INPUT, POWER CALCULATED FROM PRESSURE RISE AND PUMP EFFICIENCY

General Description

Type741 models a variable speed pump that is able to produce any mass flow rate between zero and its rated flow rate. The pump's power draw is calculated from pressure rise, overall pump efficiency, motor efficiency and fluid characteristics. Pump starting and stopping characteristics are not modeled. As with most pumps and fans in TRNSYS, Type741 takes mass flow rate as an input but ignores the value except in order to perform mass balance checks. Type741 sets the downstream flow rate based on its rated flow rate parameter and the current value of its control signal input.

Nomenclature

Δp	[Pa]	Pressure rise across the pump.
ρ_{fluid}	[kg/m^3]	Fluid density
$\dot{m}_{rated}$	[kg/hr]	Rated mass flow rate of fluid passing though the pump.
$\dot{m}$	[kg/hr]	Mass flow rate of fluid currently passing through the pump.
η_{motor}	[0..1]	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.
$\dot{P}$	[kJ/hr]	Power drawn the pump.
$\dot{P}_{shaft}$	[kJ/hr]	Shaft power required by the pumping process (does not include motor inefficiency)
$\dot{W}_{pumping}$	[kJ/hr]	Shaft work performed in the pumping process (does not include motor or pumping inefficiency). This value is also called the ideal work performed.
$\dot{Q}_{ambient}$	[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

If the pump is determined to be OFF due to it's control signal being set to 0, the pump mass flow rate, power drawn, energy transferred from the pump to ambient and energy transferred from the pump to the fluid stream are all set to zero. The temperature of fluid exiting the pump under the OFF condition is set to the temperature of fluid at the pump inlet. If however the pump is determined to be ON (control signal greater than 0) then the mass flow rate of fluid exiting the pump is set based on equation 741.1

$$\dot{m} = \gamma \, \dot{m}_{rated} \qquad \text{(Eq. 741.1)}$$

Where γ is the user specified pump control signal varying between 0 and 1. The efficiency of pumping the fluid from its inlet to its outlet pressure is given by equation 741.2

$$\eta_{pumping} = \frac{\eta_{overall}}{\eta_{motor}} \quad \text{(Eq. 741.2)}$$

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:

$$\eta_{overall} = \frac{\dot{v}_{rated}\ \Delta p_{rated}}{\dot{P}_{rated}} \quad \text{(Eq. 741.3)}$$

The ideal work done in pumping the fluid is given by

$$\dot{W}_{pumping} = \frac{\Delta p\ \dot{m}}{\rho_{fluid}} \quad \text{(Eq. 741.4)}$$

The work done at the pump shaft takes into account the inefficiency of the pumping process as calculated in equation 741.3

$$\dot{P}_{shaft} = \frac{\dot{W}_{pumping}}{\eta_{pumping}} \quad \text{(Eq. 741.5)}$$

The total power drawn by the pump includes the effects of motor inefficiency as shown in equation 741.6.

$$\dot{P} = \frac{\dot{P}_{shaft}}{\eta_{motor}} \quad \text{(Eq. 741.6)}$$

Energy transferred from the pump motor to the fluid stream is calculated as shown in equation 741.7

$$\dot{Q}_{fluid} = \dot{P}_{shaft}\left(1 - \eta_{pumping}\right) + \left(\dot{P} - \dot{P}_{shaft}\right) f_{motorloss} \quad \text{(Eq. 741.7)}$$

In which $\eta_{pumping}$ 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 from the pump motor to the ambient is given by equation 741.8.

$$\dot{Q}_{ambient} = \left(\dot{P} - \dot{P}_{shaft}\right)\left(1 - f_{motorloss}\right) \quad \text{(Eq. 741.8)}$$

The temperature of fluid exiting the pump can now be calculated as shown in equation 741.9.

$$T_{fluid,out} = T_{fluid,in} + \frac{\dot{Q}_{fluid}}{\dot{m}_{fluid}} \quad \text{(Eq. 741.9)}$$

Type741 does not model pump starting and stopping characteristics. As soon as the control signal indicates that the pump should be ON, the outlet flow of fluid jumps to the corresponding condition because the time constants with which pumps react to control signal changes is much shorter than the typical time steps used in hydronic simulations. Type741 also operates as many pump and fan models do in TRNSYS. That is to say that they ignore the fluid mass flow rate provided as an input to the model except so as to perform a mass balance on the pump. Therefore care must be taken in specifying fluid loops with multiple pumps that inlet mass flow rates greater than the rated mass flow rate for a given pump are not specified. The total number of time steps during which the fluid inlet mass flow rate for Type741 is not equal to its outlet flow rate is reported to the list file at the end of each simulation.