Relationship between pump total head and discharge pressure

The discharge pressure of a pump is not the same as the value in which the total head shown in the performance curve of the pump is converted into pressure.

1. Abbreviation

H : Total head (m)

H_d : Discharge head referred to pump shaft center (m)

H_s : Suction head referred to pump shaft center (m)

v_d : Discharge velocity (m/s)

v_s : Suction velocity (m/s)

g : Acceleration of gravity (m/s^2)

$v_d{}^2/2g$: Discharge velocity head (m)

$v_s{}^2/2g$: Suction velocity head (m)

ρ : Density of liquid handled (g/cm^3)

P_d : Discharge pressure (kg/cm^2) $= \rho H_d/10$

P_s : Suction pressure (kg/cm^2) $= \rho H_s/10$

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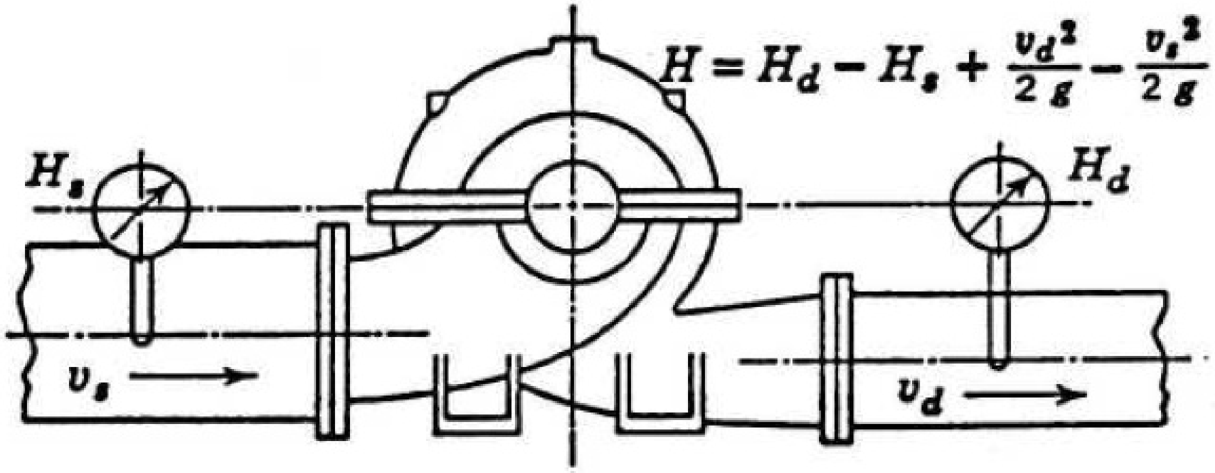

Fig. 1 Reference figure

Relationship between pump total head and discharge pressure

2． Definition of total head H

The total head is a value in which the energy that the liquid obtained by operating a pump is displayed by total head, therefore it becomes total head difference between the discharge and the suction of the pump in normal height. The normal height is the shaft center in horizontal pumps.

The discharge head and the suction head can measure only the static pressure as they measure with pressure gauges at the performance test of the pump. However, while operating the pump, the liquid with suction velocity flows from the pump suction, and the liquid that gains discharge velocity flows out from pump discharge. The energy of suction velocity and discharge velocity is called dynamic pressure. Because the total head H is energy shown by head instead of the total pressure, it becomes the sum of static pressure and dynamic pressure.

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3. Calculating formula of total head H

Here, H_d: Discharge head referred to pump shaft center (m), H_s: Suction head referred to pump shaft center (m), v_d : Discharge velocity (m/s), v_s : Suction velocity (m/s), g : Acceleration of gravity (m/s^2), then because total head H (m) is total head difference between the discharge and the suction of the pump in normal height;

$$H = (H_d + v_d{}^2/2g) - (H_s + v_s{}^2/2g) = H_d - H_s + v_d{}^2/2g - v_s{}^2/2g \quad \cdots\cdots (1.1)$$

When the discharge bore size is the same as the suction one;

Velocity difference $(v_d{}^2/2g - v_s{}^2/2g) = 0$

Then;

$$H = H_d - H_s \quad \cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots (1.2)$$

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4. Discharge pressure

From the formula (1.1), discharge head H_d (m) is;

$$H_d = H + H_s - v_d^2/2g + v_s^2/2g = H - (v_d^2/2g - v_s^2/2g) + H_s \quad \cdots\cdots (1.3)$$

In a word, discharge head H_d (m) is the value that subtracts total head difference between discharge velocity head and suction one $(v_d^2/2g - v_s^2/2g)$ from total head H (m), and adds suction head H_s (m). Then;

$$H_d \neq H$$

Discharge head Hd (m) always varies with suction head Hs (m).

Here ρ : Density of liquid handled (g/cm^3), converting discharge head H_d (m) into discharge pressure P_d (kg/cm2);

$$P_d = \rho H_d/10 \quad \cdots\cdots (1.4)$$

Also suction pressure P_s (kg/cm^2) is;

$$P_s = \rho H_s/10 \quad \cdots\cdots (1.5)$$

Relationship between pump total head and discharge pressure

From the formula (1.3), discharge pressure P_d (kg/cm2) is;

$$P_d = \rho H/10 - \rho (v_d{}^2/2g - v_s{}^2/2g)/10 + P_s$$

When the discharge bore size is the same as the suction one;

Velocity difference $(v_d{}^2/2g - v_s{}^2/2g) = 0$

Then;

$$H_d = H + H_s$$

$$P_d = \rho H/10 + P_s$$

5． Height of pressure gauges

In **Fig. 1**, the pressure gauges are at the shaft center in horizontal pump. Then, when the pressure gauges are not at the shaft center, what do discharge head H_{d1} (m) and suction head H_{s1} (m) become? The indication value decreases to the extent that the pressure gauges rise more than the shaft center. When discharge gauge height ΔH_d (m) and suction gauge height ΔH_s (m) are respectively higher than the shaft center, Discharge head H_d (m) and suction head H_s (m) are as follows.

$$H_d = H_{d1} + \Delta H_d \quad \cdots\cdots (1.6)$$

$$H_s = H_{s1} + \Delta H_s \quad \cdots\cdots (1.7)$$

6. Calculation example

In these case;

Flow rate Q = 1.9 m3/min, Discharge head H_{d1} = 150 m, Suction head H_{s1} = 20 m, Discharge bore size D_d = 80 mm, Suction bore size D_s = 100 mm, Discharge gauge height ΔH_d = 0.3 m, Suction gauge height ΔH_s = 0.1 m, Density of liquid handled ρ = 0.78 g/cm^3;

Calculate Total head H (m), Discharge pressure P_d (kg/cm^2) and Suction pressure P_s (kg/cm^2).

From the formula (1.6),

$$H_d = H_{d1} + \Delta H_d = 150 + 0.3 = 150.3 \text{ m}$$

From the formula (1.7),

$$H_s = H_{s1} + \Delta H_s = 20 + 0.1 = 20.1 \text{ m}$$

Relationship between pump total head and discharge pressure

Discharge velocity v_d (m/s),

$$v_d = (Q/60)/\{\pi/4x(D_d/1000)^2\} = (1.9/60)/\{\pi/4x(80/1000)^2\} = 6.3 \text{ m/s}$$

Suction velocity v_s (m/s),

$$v_s = (Q/60)/\{\pi/4x(D_s/1000)^2\} = (1.9/60)/\{\pi/4x(100/1000)^2\} = 4.0 \text{ m/s}$$

From the formula (1.1), Total head H (m),

$$H = H_d - H_s + v_d^2/2g - v_s^2/2g$$

$$= 150.3 - 20.1 + 6.3^2/(2x9.81) - 4.0^2/(2x9.81)$$

$$= 131.4 \text{ m}$$

From the formula (1.4), Discharge pressure P_d (kg/cm^2),

$$P_d = \rho H_d/10 = 0.78 \text{ x } 150.3/10 = 11.7 \text{ kg/cm}^2$$

From the formula (1.5), Suction pressure P_s (kg/cm^2),

$$P_s = \rho H_s/10 = 0.78 \text{ x } 20.1/10 = 1.57 \text{ kg/cm}^2$$