

The effect on pump efficiency and energy by the additional design margin of motor power

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Abstract

This paper is the result of pump performance test that has the aim to suggest an another way of the pump design based on the energy saving. In the pump used in building facility, the shaft power is calculated by the total head and capacity applying the listing pump efficiency according the shape of pump. Also the motor output is calculated by applying the margin of loss according to the connecting state of the shaft and the motor. Then it is the general way to choose the higher standard model than the above calculated motor output in deciding the size of pump lastly. In result the motor output is often determined in too large size by adding the additional margin. Therefore it is necessary to certificate whether this way is the most effective method in the aspect of the energy consumption and the efficiency. This research suggests the another advanced way. It is to choose the motor output size with no considering the additional margin than the higher model that the additional margin is added unconditionally from the calculated motor output. This paper is the research for the relative relationship of the power margin rate and the efficiency in design of pump model. In the result of the pump performance test by two model pumps choosen in the general way, and suggested way which is higher about 17% in the aspect of the efficiency and higher about 18% in the energy saving comparing with the general method. Finally this research shows that the suggested method is an applicabal way to save energy by using the most appropriate pump.

Keywords : motor power(output), pump performance test, energy saving, efficiency, additional margin

1. Introduction

Recently there has been the effort to solve the problem according to a rising trend of the oil price and the limit of fossil fuel in the various fields. Generally to save the energy, we can approach the way to reduce the using of energy or to approve the utilizing efficiency of energy. In the case of a building, according to a grand scale and higher stories the total head and capacity become larger, and the energy consumption is increasing continuacely.

Normally the setting up of pump is necessary in the sanitational facility etc, and the shaft power is

calculated theoritically by the necessary total head, capacity and pump efficiency according to the type of pump. The motor power(output) is calculated by applying the loss by connection with motor shaft in the base of the above shaft power. Also to suit the standard size the additional power margin makes the size overplus than the requirement.

So this research aims to know how the additional margin cause the effect to the pump efficiency.

To achieve this purpose there is a difficult problem that the pump should be made and tested by many additional margin rate according to the given pumping up condition. So in this research the two pumps - with additional margin and no additional margin - are considered.

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2. Research and calculation method of pump power

2-1. Definition and water power

The pump can be divided into Volume, Non Volume and Special type, and the centrifugal pump that centrifugal power to the inletted water is transferred to pressure energy by impeller's rotation.

So in this research, the centrifugal pump is the object and two pumps with an additional margin and no margin in the condition of given capacity and pump efficiency are made for the performance.

The capacity of pump is the quantity of water per unit time(m³/min), and the total head is the height(m) to the water surface from the center of the pump considering the frictional loss.

The ability of pump is appeared by the capacity, total head and the motor power.(the diameter of pump's outlet can be added)

The main terms using in this research is defined as followings.

- water power : the theoretical power to pumping out the water
- shaft power: the power concluding the loss of pump shaft adding to the water power
- motor power : the out put power of pump that the loss connected to the motor shaft is considered
- required electric power : the input electric power considering the motor efficiency
- pump efficiency : the rate of water power to shaft power(higher rate is higher efficiency)
- motor efficiency : the rate of output power to input power of motor
- performance curve : the total head and the shaft power are presented in graph according to the change of pump's flux

As the above, the pump size is presented by the total head, capacity and power that is proportioned to the product of capacity and head.

Namely in a pump facility, setting the total head in H(m), the capacity(flux) in Q(m³/min), then the water power of pump is that

$$L_w = \frac{1,000 \times Q \times H}{6,120} \dots\dots\dots(1)$$

$$= 0.163QH(KW)$$

2-2. Condition of pumping up

In this research the given pumping up condition following.

Total head : 40 M

Capacity : 4.96 m³/min

The necessary diameter of pump can be taken by the following formula.

$$Q = \Pi d^2/4 * v \dots\dots\dots(2)$$

where, Q : capacity(m³/s)

d : pump diameter(m)

v : velocity(m/s)

The calculation of the shaft power is determined by dividing the water power as pump efficiency, and centrifugal pump the pump efficiency is followed by the diameter of pump generally.

Table1. pump efficiency

Diameter of pump (mm)	65	80	100	125	150	175	200	225
pump efficiency (%)	45 ~55	50 ~62	55 ~65	64 ~72	66 ~75	68 ~76	70 ~78	76 ~80

From the above(2) and table.1 the theoretical pump efficiency is about 70% since the diameter of pump 0.19m when the velocity of water is 3 m/s.

Hence the shaft power applying the theoretical pump efficiency is taken by following (3).

$$L_s = \frac{L_w}{\eta} \dots\dots\dots(3)$$

Also, the motor output is generally calculated as follows (4) considering the loss of motor shaft connection.

$$L_m = L_s (1+\mathcal{L}) \dots\dots\dots(4)$$

where, ($\mathcal{L}$: 0.1~0.2)

In this research, the two pumps of motor direct

connected centrifugal pump -the case of the additional margin and no margin - are made, and the performance test is analyzed.

2-3. Pump size considering the additional margin

At the above formula (1) and (4), pump efficiency 0.7, the loss rate of motor shaft transfer 0.2 and the additional margin rate(a) is applied, then the motor output is as following.

$$L_m = \frac{0.163 \times 40 \times 4.96}{0.7} (1+ 0.2+ a) \dots\dots\dots(5)$$

Here the additional margin rate (a) is not determined as a particular value, and it is corresponded to the difference of the power with no margin and power of higher(one step) standard size than no margin's power.

2-4. Pump size with no considering the additional margin

At the above formula (1) and (4), pump efficiency 0.7, the loss rate of motor shaft transfer 0.2 and no considering the additional margin rate(a), then the motor output is as following.

$$L_m = \frac{0.163 \times 40 \times 4.96}{0.7} (1+ 0.2) \dots\dots\dots(6)$$

= 55(KW)이다.

Therefore the calculated motor power is 55 KW by the following (6) with no considering (a), and the above standard size with additional margin is 75 KW. So the additional rate (a) is assumed about 0.36.

Hence two cases have big difference. The motor pumps calculated lastly by each method have the additional margin 36%, 0% respectively as like table 2.

Table2. Additional margin rate

Division		Additional rate(%)
Calculation method	Additional margin	36
	No additional margin	0

3. Method and item of performance test

3-1. Method of performance test

The voltage and total head are estimated at each flux changing the flux from 0 to 1.6 times on each pumps. The motor power can be calculated considering motor efficiency from the required electric power estimated each flux.

And pump efficiency is the rate of the shaft power water power calculated theoretically.

The graph is drawn on the flux and head, flux at shaft power and pump efficiency.

3-2. Test pump model

The pump model made by the additional margin rate are following table3 and figure1.

Table3. Test pump model

Division		Size
Test model	P ₁	40m×4.96m ³ /min×75KW
	P ₂	40m×4.96m ³ /min×55KW

Figure1. Test Pump(P₁,P₂)

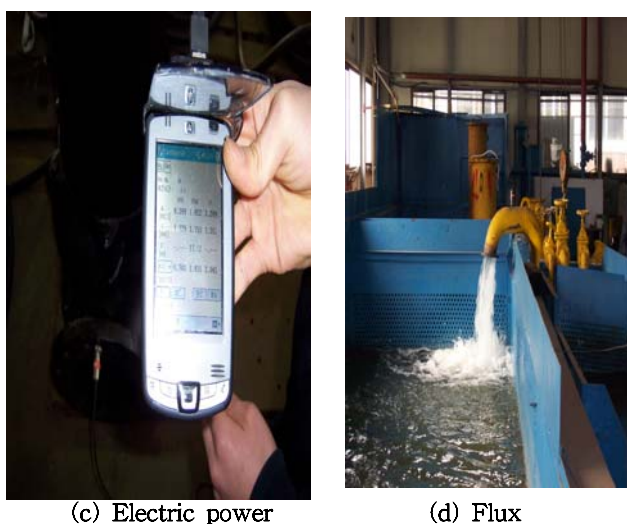
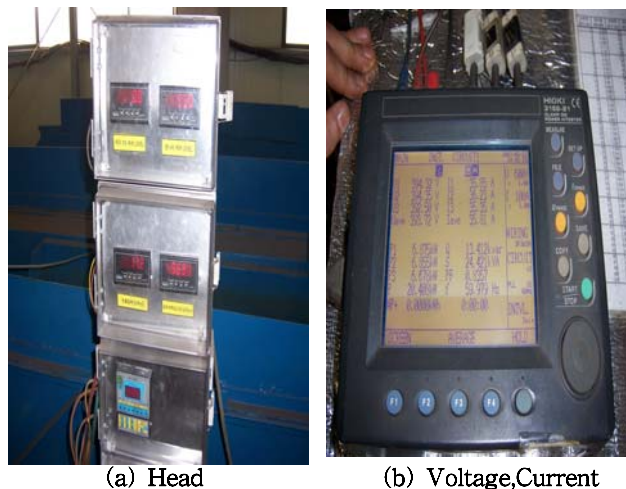


3-3. Mesuring items

About the test pump, the flux is controled(0-1.6 times) by the handling of outlet valve, so the total head, voltage, current, and electric power are calculated by corresponding to each flux(figure2).

The pump efficiency is calculated by the above test method.

Figure2. Measuring items



estimated by the instrument of the input electric power, and the motor power is times of the input power and the motor efficiency that is marked on the motor production.

Total head is the sum of the head(m) equivalent to the friction loss to the height difference(m) by pumping up.

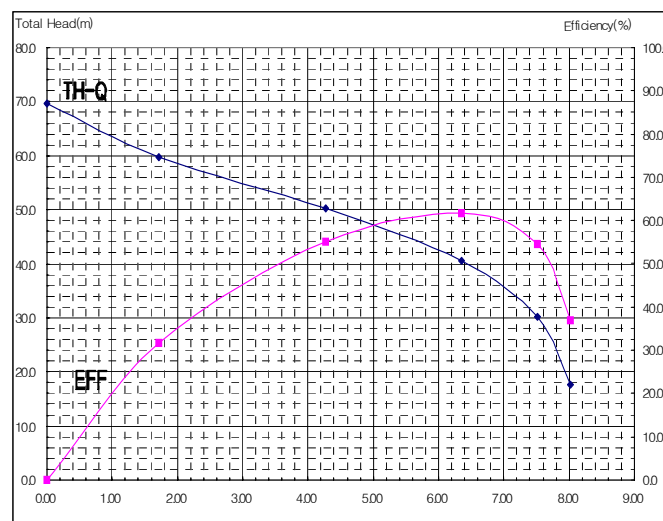
Also the flux is estimated by flux meter and the shaft power is calculated by the above test method to each flux. Furthermore the pump efficiency is judged as the rate of water power calculated theoretically.

Table4. Result of performance test(P₁)

pump model : P ₁							
	capacity (m ³ /min)	total head (m)	motor		shaft power (Kw)	water power (Kw)	pump efficiency (%)
			voltage (V)	current (A)			
1	0.000	69.7	394	78.0	31.26	0.00	0.0
2	1.708	59.8	393	115.0	52.56	16.66	31.7
3	4.264	50.2	393	136.0	63.25	34.86	55.1
4	6.359	40.6	390	148.0	68.07	42.07	61.8
5	7.509	30.1	390	148.0	67.63	36.85	54.5
6	8.022	17.6	393	132.0	62.36	23.04	37

The maximum pump efficiency is 61.8% at the total head 40.6m, flux 6.359m³/min and it has the 8.2% efficiency drop comparing with the design condition - 70% efficiency.

Figure3. Total head and capacity ,efficiency(P₁)



4. Result and analysis of pump performance test

4-1. Pump model P₁

The result of performance test to the pump model(P₁) is Table4 and it is expressed in graph as like Figure3 and 4.

Here, the voltage and current of the motor are

Figure4. Shaft power and capacity(P1)

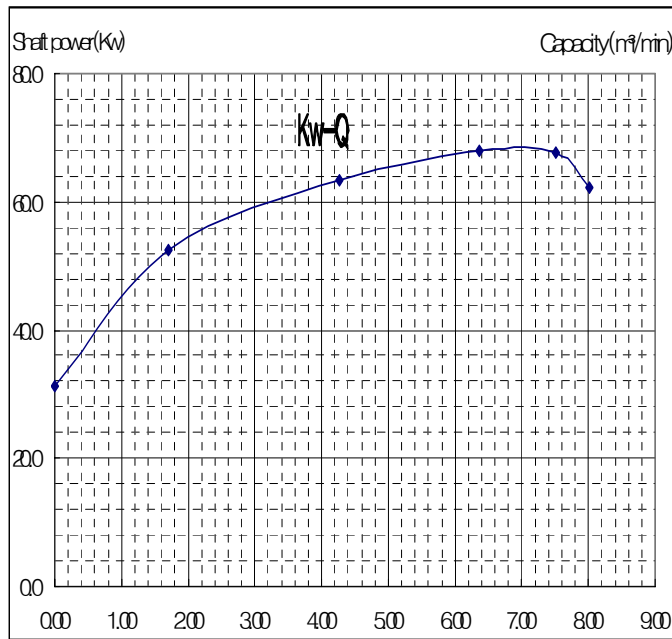
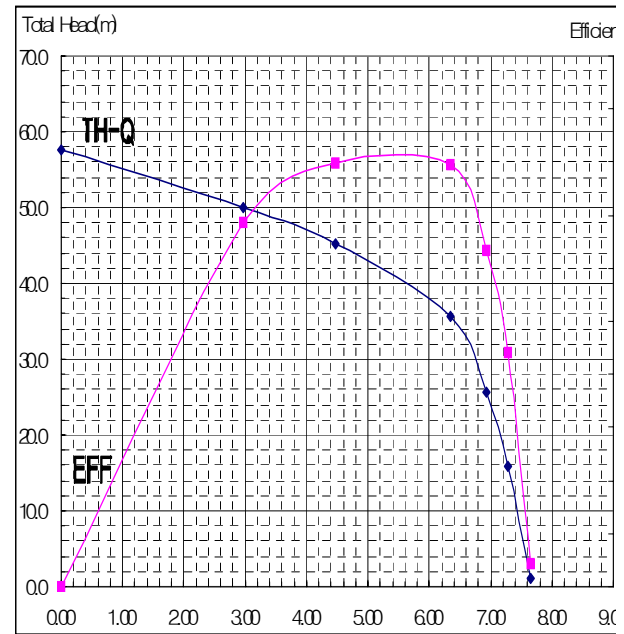


Figure6. Total head and capacity, efficiency(P2)



4-2. Pump model P₂

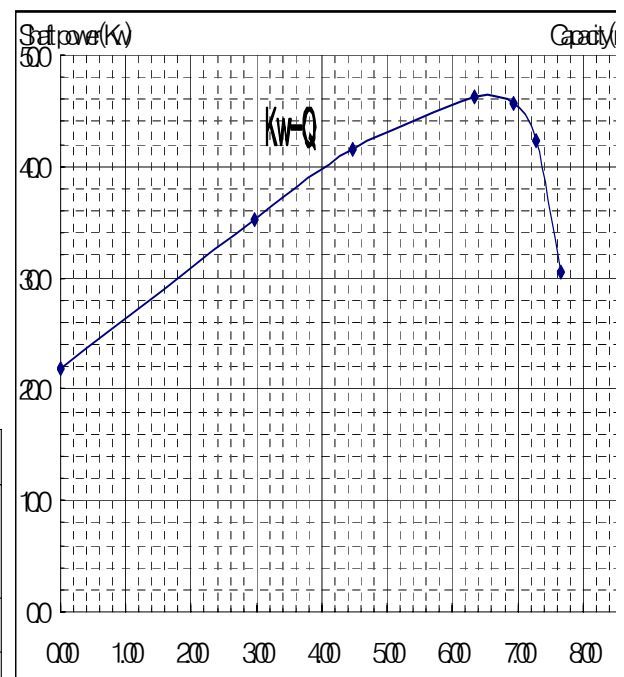
The result of the performance test to the pump model(P₂) is as like the Table5, and it is expressed to Figure6,7.

The maximum pump efficiency is 79.7% at the total head 45.3m, flux 4.472m³/min and the pump efficiency is about 79% at the given condition (40m×4.96m³/min), so it has the 9% efficiency up comparing with the design condition - 70% efficiency.

Table5. Result of performance test(P2)

pump model : P ₂							
	capacity (m ³ /m)	total head (m)	motor		shaft power (Kw)	water power (Kw)	pump efficiency (%)
			voltage (V)	current (A)			
1	0.000	57.6	396	49.1	21.77	0.00	0.0
2	2.962	50.1	395	71.9	35.21	24.20	68.7
3	4.472	45.3	394	83.3	41.44	33.01	79.7
4	6.340	35.6	394	92.2	46.18	36.77	79.6
5	6.937	25.7	394	91.4	45.74	27.05	63.5
6	7.286	15.8	394	84.3	42.41	18.72	44.1
7	7.660	1.0	396	63.5	30.55	1.30	4.3

Figure7. Shaft power and capacity(P2)



4-3. Comparison of the efficiency and the power

The comparison of the result about the above test model pump shows the actual efficiency and shaft power at the given design condition(40m×4.96m³/min) is mentioned on the table 6.

Table6. Comparison of the pump efficiency and the shaft power

Test pump	Efficiency (%)	Shaft power(KW)	Remarks
P ₁	61.8	61	considering additional margin
P ₂	79.0	43	considering no additional margin

Namely the pump P₂ with no additional margin is higher about 17% in efficiency, and can save about 18% in energy than pump P₁ by the general method considering the additional margin.

Because the maximum shaft power of no considering the additional margin is about 46KW, it has about the biggest value $\mathcal{L}$ in the formula(4).

This means there is no problem in function and safety owing to the improvement of pump technology etc.

5. Conclusion

In design of pump the selection of size to fit the condition of total head and capacity is the important point in aspect of energy consumption.

Because the consumption of energy occurs throughout the year, the various ways to improve the efficiency are necessary.

In the calculation of pump size, the general method till now - considering the additional margin to fit the standard size - is not efficient in the aspect of efficiency and energy.

This research shows consequently that the power size not considering the additional margin is higher about 17% in the efficiency and energy saving is about 18% than the case of considering the additional margin.

In the concluding, this research shows that the method of no considering the additional design margin to fit the standard model is more effective and more reasonable in the aspect of pump efficiency, and energy saving.

Provided that the result value of the efficiency and shaft power in this research can be corrected to reasonable value in the pump test by the additional various condition.

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