Feasibility Study of Microhydro Power Plant on Kalimaja River In Dusun Kedondong Rame Ruguk Village Ketapang District Lampung South

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Abstract. Electricity is one of the primary needs of human life that needed an efficient power plant. Power microhydro (MHP) is an alternative source of electrical energy for the community. MHP provides many advantages, especially for rural communities throughout Indonesia. While other energy thinning and a negative impact, then the water becomes a very important energy source because it can be used as a source of cheap energy power plants and does not cause pollution.This study aims to provide information to the Community, especially Hamlet KedondongRame that the availability of the potential provided by nature can be used as a source of electric power. This research was conducted by analyzing the feasibility of the River Kalimaja as micro hydro power plant which includes the water flow, the height waterfall and accuracy in the use of turbine type.Selection of the type of turbine used is influenced by the high discharge and falling water. Based on data collection in the field and based on the importance of the minimum flow of0.0610 / s and *head* 21.96 meters effectiveand specific speed 65.95 rpm, the turbine used in the design of the planning study isturbine*Cross-Flowtype.* Keywords: MHP,*Cross-Flow*

1. Introduction

Electricis one of the necessities of life (MHP) is an alternative energy source of primary human so that the necessary electricity for the community. MHP provides an efficient power plant. many advantages especially for the community therefore needed, thesources inlandthroughout Indonesia. While energy alternative energyto overcome the scarcit of other thinning and impact energies, negative, then the water becomes the energy source power plant microhydro is very important because it can be used as the best choice in many aspects of power generation energy sources are cheap compared with other types of renewable energy (energy and non-polluting. New and Renewable) others. Power microhydro (MHP) refers to power plants with Mechanical Engineering, Planning System Design MHP scale below 100 kW. Many rural areas in Indonesia that is close to the river flow sufficient to build a power plant *microhydro* (MHP). It is expected that by utilizing the potential that exists in these villages can meet its own energy needs in anticipation of rising energy costs or difficulties national electricity network to reach them. *Microhydro* or what is meant byPower Lisrtik plants *micro hydro* (MHP), is a small-scale power plants that use water as a driving force such as irrigation canals, rivers or natural waterfall by utilizing the high*(head)*terjunaan and the amount of water flow. In the village Ruguk Ketapang District of Lampung Southregency, Lampung, there is a village / settlement is far from the reach of electricity. This hamlet is occupied by the 15 heads of family with their daily livelihood is farming. In the village there is a potential availability of sufficient waterfalls throughout the year, with a minimum discharge flow (dry season) 0.0610 (/ s) or about 61 liters / second and has a height difference*(Head)*of approximately 22 meters from the top surface to below the surface. Due to the limitations of cost and lack of public knowledge about the potential of the river you have, the author intends to be the bridge / intermediary that Hamlet KedondongRame is no longer a shortage of electrical energy, because today most local residents using solar and diesel as a source of electrical energy. Therefore, prior to the construction of power plants in the hamlet kedondongmicrohydro crowded to meet the needs of rural communities who totaled 15 head keluaraga then, theoretically assessment needs to be done to calculate the electrical power produced MHP Kalimaja Sungai Dusun Kedondong Rame. Related to this study and adjusting of the flow rate and head, the authors chose to use bine *cross-flow* types turbine types *Cross-flow* are selected based on several considerations, including:

1. The potential amount of flow and the height difference*(head)*owned Kalimaja Sungai Dusun KedondongRame.
2. The advantages possessed by the type ofturbine*cross-flow* itself. The use ofturbine type *cross-flow* is more advantageous than the use of a water mill or other turbine types. The use of these turbines of the same power can save the cost savings of up to 50% prime movers of the use of waterwheels with materials.

Mechanical Engineering, Planning MHP System Design together. These savings can be achieved because of the size of theturbines*cross-flow* are smaller and more compact than the waterwheel. Runernya diameter water wheel that is usually 2 meters and above, whereas forturbine diameter *cross-flow* can be made only 20 cm,so that the materials needed less. Likewise, the effectiveness or efficiency of the turbine is on average higher than the waterwheel. The high efficiency of the turbine *cross-flow* due to utilization of water energythe turbine is done twice, the first collision energy of water on the blades when the water came in, and the second is the thrust of the water on the blades of time will leave runer. The presence of work water-riseturned out to provide advantages in terms of high effectiveness and simplicity in water dispensing system of runer.

2. Literature Review

Microhydro power plants (MHP) is a power generation bersekala small (less than 100 kW), which harness the flow of water as a source of energy. Hydropower is a form of hydroelectric power changes with altitude and specific discharge into electric power, using the power turbine and generator. [Rizal Firmansyah] Based on the discharge capacityplant hydroelectric power(HEPP) can be classified as follows:

Table 1. Classification of hydropower

No.	Typehydropower	capacity>
1	Hydropower Large	100 MW
2	hydropowerMedium	MW15-100
3	Small Hydroelectric	1-15 MW
4	micro power (minihydro)	100 kW-1 MW
5	MHP (microhydro)	5 kW- 100 kW
6	PicoHydro	<5 kW

Source: [Prayogo. 2003]

Fritz Dietzel 1980 also states that it's great flow turbine used for a small hydroelectric facility and a power of approximately 750 kW. High water falls that can be used above 1 meter to 200 meters with a water capacity of 0,002 / s up to 7 / s yield / efficiency of Approximately 80% with a speed of rotational 60 to 200 depending on the diameter of a wheel.

2.1 Working Principle of MHP

Ascheme *micro hydro* requires two things, namely, the water discharge and the height of fall (head) to produce energy that can be harnessed. This is an energy conversion system of the form and the height of the flow (potential energy) into the form of mechanical energy and electrical energy. [Dolald. 1994]

2.2 Component Kompenen MHP

Technically, *microhydro* has three main components: water (source of energy), turbine and generator [YSH NugrohoHunggul 2015]. Dam made of earth, Mechanical Engineering, Planning System Design MHP stone or concrete built across the river. The availability of a reservoir a lot of help in order to be somewhat uneven burden borne by the rainy season and dry season. Thus hydropower can be operated optimally (Figure 2.1.2.1). [Abdul Kadir, 1996]

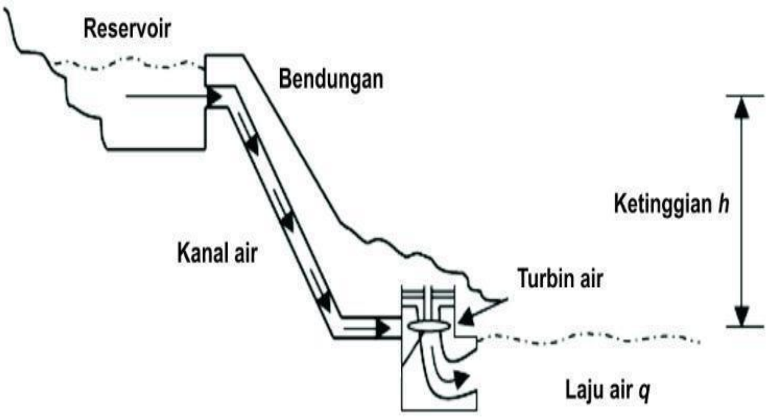

Figure 1. Components of the MHP [Source: Abdul Kadir, 1996]

1. Creeks

To determine the flow rates can be used the following equation.*[Munsonet al*.2013]

Q = V x A (equation 1)

Where:

Q: Discharge of water used ()

V: Water flow rate (m /

A s):Cross-sectional area rapidly pipes(penstocks)

2. Turbine

Turbine is the most important part ofunit. *microhydro*In the turbine water flow changedinto kinetic energy that would rotate the rotor (wheel). [Source: Hunggul YSH Nugroho]

Table 2. Type turbines

Type Turbine	**High Head 30 m**	**Medium Head 10-30 m**	**Low Head <10 m>**
impluse	Pelton Turgo	Crossflow Multi jet Pelton Turgo	Crossflow

[source, Hunggul YSH Nugroho and M. KudengSallata]

The selection of the turbine can be determined based on the advantages and disadvantages of the types of turbines, especially for a very specific design. High factor of falling water is effective*(nethead)*and debit cards will be used for the operation of the turbine is a major factor that affects the choice of turbines, for example turbine platoon effective for operations on the high fall-out of water*(head)*high, while the turbine propeller is very effective for surgery on a high dropping water*(head)*is low. Power factor*(power)*is desired with regard to high water fall*(head)*and a simple discharge. [Ismono 1999]

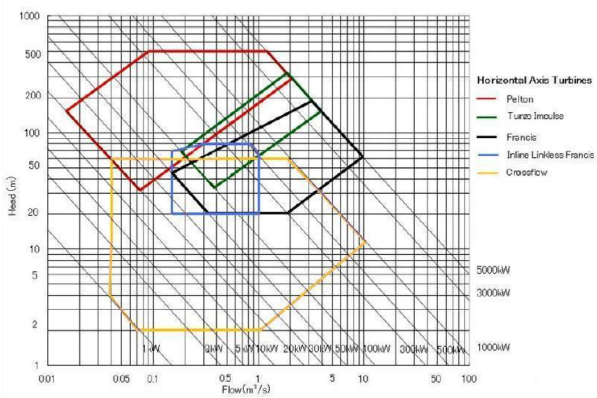

Figure 2. Selection of turbine type by *head* and *flow* [Source: Tanaka Suryoku Turbine]

The turbine is also distinguished by the way it works is impluse and Turbi reaction turbine. Impluse turbine is a type of turbine that converts all the energy of water into kinetic energy that would rotate the turbine, thus producing a torsional energy. While the turbine is a reaction turbine
Mechanical Engineering, Planning System Design MHP converts water energy directly into torsional energy. [Hunggul YSH Nugroho and M. KudengSallata 2015]
3. Generators
Synchronous (also called alternator) is a synchronous machine that converts mechanical energy into electrical energy alternating (AC). The advantages of an alternating current (AC) is to distribute power at a considerable distance. Almost all of the electrical energy generated using synchronous generator. Generator synchronous generator can be synchronized 3-phase or 1-phase synchronous generator. 3 phase system means there are 3 cables can be powered from a generator. While one phase of the generator means there is only one cable is plugged into. In terms of efficiency, the use phase can reduce the amperage and automatically reduces the size of the cable diameter. No synchronous generator capacity ranging from low or high power. But in general, high-capacity semakain generator size will become bigger and bigger. For example, 10 KVA generator will be larger and heavier than the 3 KVA, as well as pull betrat rotor rotation. [Source: Hunggul YSH Nugroh]

3. Research Methods

3.1 Research Sites

This research was conducted at the River Village KalimajaRugukKetapang District of South Lampung regency. The choice of location is based on the consideration to facilitate the author in collecting data related to the research and to minimize the cost of doing research because the location of the object is not too far from the residence of the writer.

3.2 Data Collection

Data *Primary* is data obtained directly from the field. Sources of primary data obtained by directly measuring the flow of water and the height difference*(Head)*on the river Kalimaja Hamlet Kedondong Rame. data *Secondary* is data obtained indirectly or through an intermediary medium. The data obtained through library*(LibraryResearch)*reading, studying, cites and examines the literature that support and relate to the issues to be discussed.

3.3 Data Collection Method

The method used to measure the discharge is by making stakes on both sides of the river. Then tie the rope on both sides of the peg so that the rope stretched from one river bank to the other bank of the river can therefore measured the width of the river discharge.

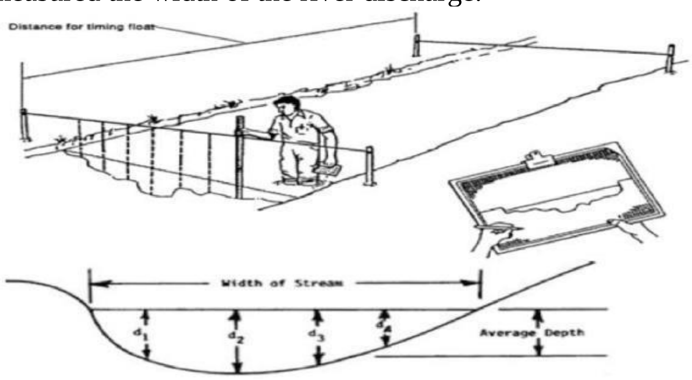

Figure 3. Divide the Measurement Segment [Sutarno, 1993]

Head measured is a gross head (gross head), after reducing the friction factor and loss factor (losses) other when water flows will be net head (head net). This head measurement using a simple measurement that uses a strand of nylon and plastic hoses. The way it works is:

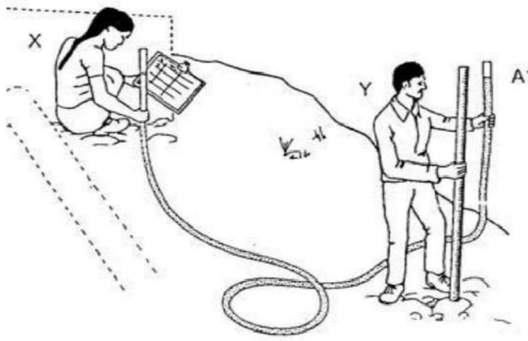

Figure 4. How to measure the level water to the position *forebay* [Sutarno, 1993]

4. Results and Discussion

4.1 Water Resources

Before water power calculation teorotis need for the calculation of losses and high effective on the pipe rapidly. Fordetermine the magnitude of the flow rate of water can be used the following equation [Munson et al. 2013].

a. The water velocity in the pipe

$$v = \frac{Q}{A} \longrightarrow A = \frac{1}{4} \text{ x } \pi \text{ x } D^2$$

$$v = \frac{0{,}0610 m^3}{0{,}0323 m^2} \quad (1)$$

v = 1.8885 m / s = 1888.5 mm / s

Where:
V: velocity water flow (m / s)
Q: Discharge of water used ()
A: sectional area of the pipe rapidly*(penstocks)*(D: Diameter pipe rapid

b. Major *losses*

Major losses are losses caused by the friction factor between the fluid water to the pipe wall. And to determine the amount of loss due to friction or *head mayor* can use the following equation [Munson et al. 2013].

$$H_{L\,(Mayor)} = f \frac{l.v^2}{D.2.g}$$

$$H_{L\,(Mayor)} = 0{,}015 \frac{44{,}7.(0{,}542)^2}{0{,}3785 \ x\ 2\ x\ 9{,}81}$$

$$H_{L\,(Mayor)} = 0{,}0297\ m = 29{,}7 \text{ mm} \quad (2)$$

Where:
(: Losses*head*because of friction (m):
d pesar Pipe Diameter (m) l: Length of pipe rapidly (m)
v: fluid flow velocity (m / s)
g: Acceleration of gravity
f: friction coefficient rapidly assumed based on roughness pipe will be used in planning. [Mafrudin 2016]

c. Minor *Losses*

Representsloss*head* caused by pipe bends, pipe and the downsizing of the nozzle. With their turn, the downsizing and the nozzle would effect on the water used. To determine the amount of loss can be used minor losses following equation [Munson et al. 2013].

$$H_{L\,(Minor)} = k\,\frac{v^2}{2.g}$$

$$H_{L\,(Minor)} = 0{,}087\,\frac{(0{,}542)^2}{2\,x\,9{,}81}$$

$$H_{L\,(Minor)} = 0{,}00129\ m = 1{,}29\ \text{mm} \qquad (3)$$

(: Losses*head*(m): fluid flow velocity (m / s) g: Acceleration of gravity is assumed as coefficient the speed

d. *Head* Effective

Is a clean head, where the friction factor and turns in the pipe or nozzle is already considered by calculation. By the following equation magnitude effective head can be seen [Abdul Nasir, 2014].

$$H_e = \text{H} - H_{L\,(Mayor)} - H_{L\,(Minor)}$$

$$H_e = 22\ \text{m} - 0{,}0297\ \text{m} - 0{,}00129\ \text{m} \qquad (4)$$

$$= 21.96\ \text{m} = 21\ 960\ \text{mm}$$

Where::*Head* effective (m) H: *Head* (m) (:loss*head* due to friction (m) (: sses*head*(m) Based on the calculation of the losses occur, it can be determined the amount of water used in MHP. The calculation of the amount of water used is by the following equation [Mockmore, and Merryfield, 1949].

= ρ. g., Q

= 995.7 kg /. 9.81 m /.

21.96 m. 0.0610 m /

= 13084.5 Watt

= 13.0845 kW

Where::

The power of water (W)

ρ: The type of water (kg /)

g: force of gravity (m /): *Head* effective

Q: water flow ()

4.2 Selection of Turbine Type

Selection of the type of turbine can be determined based on the advantages and disadvantages of the types of turbines, especially for a design to specifications at an early stage turbine type selection can be calculated by taking into account the specific parameters that mempengaryhi turbine operating system.

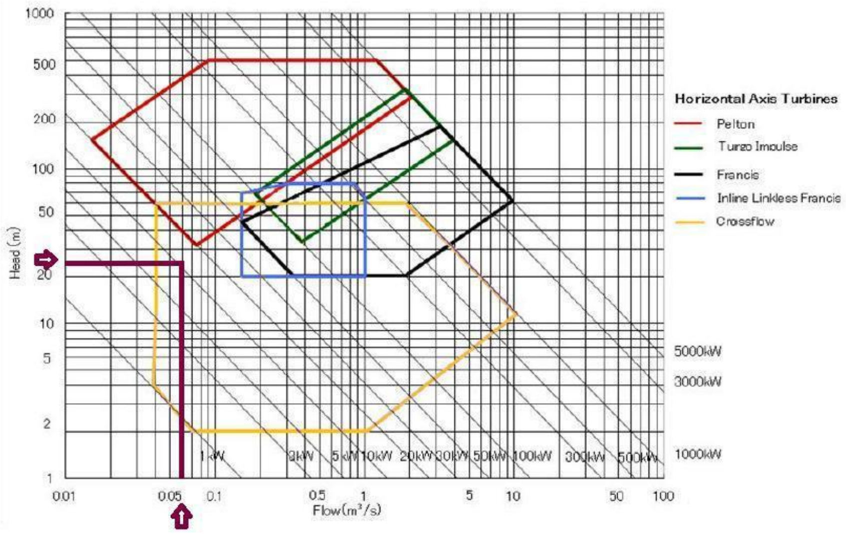

Figure 5. Crimson tangents on graph shown by the two sons

Arrowis a meeting between the data flow of water and the height difference / head effective kalimaja river. At the meeting of the two tangents can be seen that the working area is crossed by the line of the work area cross-flow turbine. As for other types of turbines, such as turbine or turbines francispelton not bypassed tangent discharge data and *head*. Turbines not only have a work area, the turbine also has a different way of working.

Table 3. Comparative analysis Use of turbine

No.	Turbine By How It Works	Type Turbine		
1	Impluse	Pelton/ Turgo	*Cross-Flow*	*Cross-Flow*
2	Reaction		*Francis*	*Propeller Kaplan*

1. (impluse) peltonturbine, Cross-Flow, *Turgo*works by changingall the energy of water into kinetic energy that would rotate the turbine, thus producing a torsional energy.
2. (Reaction)Turbine, *Francis Propeller, Kaplan,* works by changing the energy of water directly into torsional energy.

No	Turbine	Debit	Head	workings
1	Pelton / tour Go	Was	<200 m	impluse
2	**Cross-Flow**	**Lower**	**10-200 m**	**impluse**
2	Francis	Low	10-200	Reaction
m3	Kaplan /Pr> opeller	High	40	Reaction
Data	River Kalimaja	**61 l / sec (low)**	**21.96 m**	**impluse**

Based on the above analysis, which has the fit of the data in accordance with its area closest to the altitude data, discharge and how to work with this type of turbine flow is cross-flow. Based on these parameters is carried out to determine the type of turbine that will be used in this study refers to the high fall, a minimum flow and ways of working, then this type of turbine is selected referring to how the turbine is impluse with a height of 10-200 meters.

4.3 Fundamental reasons Electoral Cross-Flow Turbine type in Research

1. Based on data obtained with a height of 21.96 m and using energy penghatar water pipe as a whole to move the blade with the discharge of 61 liters / second, the chosen turbine type of *Cross-Flow* as a medium of motion. This is because the existing data in the field is the area ofturbine working *cross-flow* in the chart above.
2. Turbine cross-flow turbine is the most simple and easy to be created manually. Making the cross-flow turbine can be made dibengkel-small workshop that is common in the countryside. Unlike premises pelton type turbine, propeller, kaplan, nor francis whose creation requires a special effort because the process must by way of a cast, so to use in rural areas requires a fairly high cost.

4.4 Turbine Efficiency

Turbine cross-flow turbine having an efficiency of no less premises other turbine types. Although simple, but efficiency can withstand the range from to 0.800.82%. This is consistent with the statement following the German researchers. Haimerl. LA. 1960 stating *test resultslaboratory, conducted by the turbine plant Ossberger West Germany concluded that the power to the water mill of the type most superior even if only 70% while the efficiency of turbine type Cross-flow reached*

82%. Turbine this flow (cross-flow) both once used to center small hydropower and power of approximately 750 kW. High water falls that can be used above 1 meter to 200 meters with a water capacity of 0,002/ s up to 7 / s efficiency of approximately 80% with the speed of rotation of 60 to 200 depending on the diameter of the wheels turn. [Fritz Dietzel 1980] Based on previous research, the value of the efficiency of cross-flow turbine is 80% - 82%. But in this study are assumed to value the efficiency of cross-flow turbine that will be made by 60%, this is done to mengantisivasi all possibilities that will occur at the time in the field.

4.5 Planning Runner Turbine Cross-Flow

Berdasarskan water discharge and high value falls effective kalimaja river, then use the appropriate turbine is a type of *cross-flow*turbine. Planning or calculation parameters of cross-flow turbine runner using the following equations [Mockmore, and Merryfield, 1949, Rajab Yassen, 2014].

a. Outer Diameter *Runner*

RunnerTo width is assumed to match the width of the nozzle, where the width of the nozzle is made of 0.17 m, the diameter of which can be formed are: 0.230 m = 230 mm Where:

$$D_1 = \frac{2,63\ Q}{L\sqrt{H_e}}$$

$$D_1 = \frac{2,63\ x\ 0,0610\ m^3/_s}{0,17m\sqrt{21,96}\ m}$$

$D_1 =$ 0,230 m = 230 mm

Dimana :

D_1 : Diameter runner (m^2)

Q : Debit air (m^3/s)

H_e : *Head* efektif

l : Lebar Nosel (4)

b. diameter in *Runner*

$$D_2 = \frac{2}{3} D_1$$

$$D_2 = \frac{2}{3}\ 0,230\ m$$

D_2 = 0,153 m = 153 mm

Dimana :

D_1 : Diameter dalam

D_2: diameter dalam (5)

c. Speed *Runner* turbine

$$n = \frac{41,47\sqrt{H_e\ .\ Cos\ \alpha_1}}{D_1}$$

Dimana :

n : Putaran turbin (rpm)

H_e : *Head* efektif (m)

D_1 : Diameter luar *runner* (m) (6)

assumed Nesel corner *runner* in this plan is 30º.Here is a runner rotation speed based on the angle of the nozzle.

Sudut Nosel 15^{0}

$$n = \frac{41{,}47\sqrt{H_e}\cos 15^{0}}{D_1}$$

$$n = \frac{41{,}47\sqrt{21{,}96\ m}\cos 0{,}965}{0{,}230\ m}$$

$n = 840{,}37$ rpm

Sudut Nosel 30^{0}

$$n = \frac{41{,}47\sqrt{H_e}\cos 30^{0}}{D_1}$$

$$n = \frac{41{,}47\sqrt{21{,}96\ m}\cos 0{,}866}{0{,}230\ m}$$

$n = 753{,}26$ rpm

Sudut Nosel 45^{0}

$$n = \frac{41{,}47\sqrt{H_e}\cos 45^{0}}{D_1}$$

$$n = \frac{41{,}47\sqrt{21{,}96\ m}\cos 0{,}707}{0{,}230\ m}$$

$n = 596{,}38$ rpm (7)

d. Specific Speed

$$N_s = \frac{n\ .P^{\frac{1}{2}}}{H_e^{\frac{5}{4}}}$$

$$N_s = \frac{753{,}26\ .14{,}7147985^{\frac{1}{2}}}{21{,}96^{\frac{5}{4}}} \quad (8)$$

$N_s = 64{,}584$ rpm

Dimana :

N_s : Kecepatan Spesifik (rpm)

n : Kecepatan putaran turbin (rpm)

P : daya *output* turbin (kW)

H_e: *Head* efektif (m)

Q : Debit (m^3/s)

Jarak Antara Sudu dan Ketebalan sudu

$t_1 = 0{,}175\ D_1$ (Jarak Antara Sudu)

$t_1 = 0{,}175 \times 0{,}230$ m

$t_1 = 0{,}040$ m = 40 mm

Dimana :

t_1 : Jarak antara sudu (m)

D_1 : Diameter luar *runner* turbin (m)

e. The distance between the blade and blade thickness of

= 0.175 (Distance Between blade)
= 0.175 x 0.230 m
= 0,040 m = 40 mm

Where:

: The distance between the blade (m)
: outside diameter *runner* turbine(m) f. The radius of curvature of the blade
= 0.163
= 0.163 x 0.230 m
= 0.03749 m = 37.4 mm

Where::

the radius of curvature of the blade /*blade* (m)
: outside diameter *runner* turbine(m)

f. Jari-jari Kelengkungan Sudu

$r_c = 0{,}163\ D_1$

$r_c = 0{,}163 \times 0{,}230$ m

$r_c = 0{,}03749$ m = 37,4 mm

Dimana :

r_b : Jari-jari kelengkungan sudu/*blade* (m)

D_1 : Diameter luar *runner* turbin (m)

g. Number of blades N =
N =
N = 18.055 or 18 fruit Where:
N: number of blades

$$N = \frac{\pi . D_1}{t_1}$$

$$N = \frac{3{,}14 \ x \ 0{,}230}{0{,}040} \qquad (9)$$

h. Ketebalan Semburan Nozel

$$s_1 = 0{,}23 \ \frac{Q}{L\sqrt{H_e}}$$

$$s_1 = 0{,}23 \ \frac{0{,}0610 \, m^3/s}{0{,}17m\sqrt{21{,}96 \, m}} \qquad (10)$$

= 0.02107m = 21 mm Where:
spouting nozzle thickness (m)
L: Width of the blade*(runner)*turbine (m)
Q: Debit
(): *Head* effective (m)

From the calculation results obtained planning theoretically turbine turbine dimensional parameters as follows:

No.	Parameter	simbol	Value	Satuan/s
2	*Head* Effective		21 960	mm
3	Pipe DiameterRapid	D	378.5	mm
4	Rapid Pipe length	l	44 700	mm
5	Runner width	L	170	Mm
6	Outer DiameterTurbine		230	Mm
7	DiameterIn Turbine		153	Mm
8	Speed *Runner* Turbine	n	753.26	USD m
9	Distance Between blade		40	Mm
10	thickness Sudu	s	20	Mm
11	The radius of curvature of Blade		37.49	Mm
12	Number of blades	N	18.055	Buah
13	Bursts thickness Nozzle		21.7	Mm
14	angle nozzles		30	^{o}
	Speed Specification			m

Source: Calculation Result

4.6 Output power Generator

Theoretically power that can be generated can be calculated with the following equation, the overall efficiency of hydropower by (Subroto , 2002) obtained from:

η = ηt x ηg (11)

Where:

a. efisiensi Turbine: fisiensi Generator Assuming

b. EfficiencyGenerator (0.8) for mengantisifasi all possibilities that case, the efficiency of the generator assumed under plant efficiency is equal to 0.6.
c. As for the cross-flow turbine efficiency when referring to the turbine manufacturers conducted by himerl 1960 of 0.82. Because in this study will be made independently, then to anticipate all possibilities that happens, take the value assumed efficiency that is equal to 0.3.

Then the generated electric power is:

$P = \rho \times Q \times g \times h \times \eta t \times \eta g$ (12)

$P = 995.7 \times 0.0610 \times 9.81 \times 21.96 \times 0.3 \times 0.6$

P = 2355.22 Watts

P = 2 , 35 522 kW

Based MHP planning calculations Kalimaja theoretically with debit 0.0610/s and higher fall effective of 21.96 m was obtained electric power of direct measurement Based on the results obtained Kalimaja river minimum flow 0.0610 / s, the effective height of 21.96 m. Of debit and *head* on this study, the electric power that can be generated by the MHP Kalimaja amounted to 2.35522 kW.

5. Closing

5.1 Conclusions

From the discussion on design planning study it can be concluded:

1. Based on the measurement results obtained directly on the river flow Kalimaja minimum 0.0610/ s, the effective height of 21.96 m. Of debit and *head* on this study, the electric power that can be generated by the MHP Kalimaja amounted to 2.35522 kW.
2. Selection of the type of turbine used is influenced by the high discharge and falling water. Based on data collection in the field and based on the importance of the minimum flow of 0.0610 / s and *head* 21.96 meters effectiveand specific speed 65.95 rpm, the turbine used in the design of the planning study isturbine*Cross-Flowtype.*
3. In planning the design of the MHP Kalimaja turbine dimensions and design of *the runner* used are as follows:
    a. The diameter of the pipe rapidly (D): 0.3785 m length of pipe rapidly (l): 44.7 m
    b. The outer diameter of *the runner* (): 0.230 m
    c. The inner diameter 0,153 m diameter in runner (m): 0.17m
    d. The distance between 0,040 m the blade
    e. Number of blade (N): 10,055 fruit
    f. Crvature of the bladerc(0.0379m)

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