The Effective Pitch Of Scoop Blade Operating on Undershot Waterwheel With Water Current of 0.8 m/sec – 2.26 m/sec

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Abstract. The experiments and measurements already conducted to find out an effective pitch of Scoop Blade when attached at the circumference of waterwheel wheel of 800 mm diameter at varying speed of water of 0.8 m/sec to 2.26 m/sec. The measurements were made of revolution of wheel per minute and the moments created at varying blade numbers. The power generated at varying blade numbers attached on waterwheel produced by multiplying the moments and the related circumference speed of the wheel. The results show that the maximum power obtained at he number of blades 12 and 16 at a speed water below 2.26 m/sec. From these experiments, we get the pitch and diameter relationship as Pitch = (0.1962 – 0.261) wheel diameter

INTRODUCTION

Energy is still the one of the most critical issue, where the economic, environment and development being wrapped in one discussion. According to the World Hydropower Development Report 2016, it is about 17% of the world population, or about 1.2 billion of people still lack of electricity worldwide.

Globally the installed capacity of small hydropower is estimated at 78.000 MW in 2016, an increase of about 4 per cent if it is compared to the data from World Small Hydropower Development Report 2013. The total estimated small hydropower potential has also increased from World Small Hydro Power Dvelopment Report 2013 to 217 GW, an increase of more than 24 per cent. As approximately as 36 per cent of the total global small hydropower potential has been developed in 2016 [9]

Small Hydropower representing of about1.9 per cent of the world's total power capacity, or about 7 per cent of the world total renewable energy installed capacity and 6.5 per cent (< 10 MW) of the total world hydropower capacity including the pumped storage as well . As one of the world's most potential renewable energy sources, small hydropower is the fifth in the hydro energy development, compared to the large hydropower
the highest installed capacity in recent years, followed by the wind and solar power. The world issues of green and safe energy seems has pushed the development of hydropower worldwide.

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WATERWHEEL AND RIVER CURRENT

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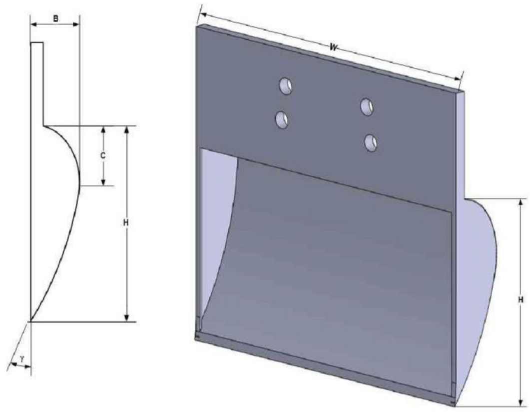

Figure 1. Scoop Blade for low current river waterwheel. [6][7]

A series of tests have been carried out to find the best 'pitch' of Scoop Blade when attached to the waterwheel of 580 mm diameter. The variable of test are the blade number around the circumference of wheel evaluated at varying speed of water. Each of blade number arrangements is evaluated at the corresponding the RPM and the power generated.

METHOD OF EXPERIMENT

The cross section area of blades facing the water current perpendicularly is (10x10) cm or equal to 100 cm^2.All blades attached on the wheel circumference were made of wood of the same shape and the same sizes. All surface of blades were painted.

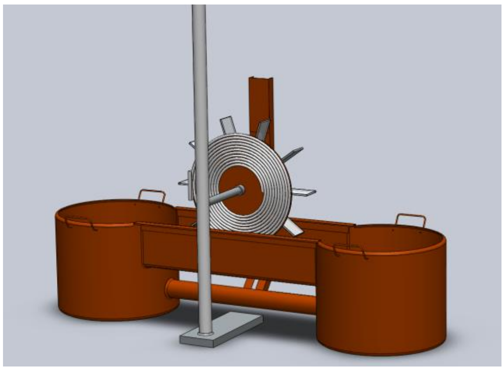

Figure 2. The test aparatus where water circulated by an immersion pump.

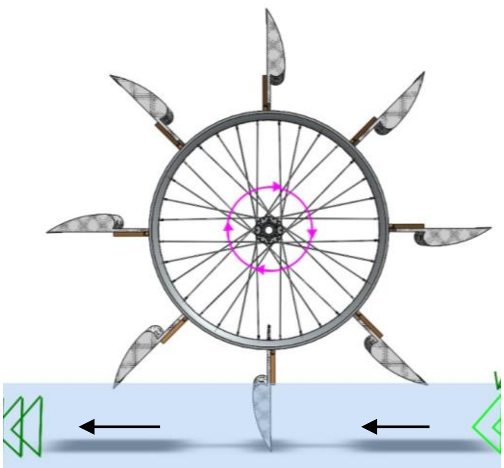

Figure 3. Eight Scoop Blades mounted on tested wheel

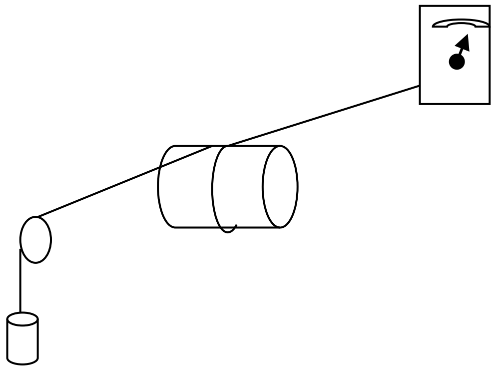

Figure 4. Torsion measurement system on the waterwheel shaft
1.Load balance. 2.Wheel shaft
3.Roll supporting the load rope 4.Load

The revolution per minute (RPM) of the wheel is counted virtually and noted on every torsion loading of the wheel shaft. The peripheral velocity of the wheel is calculated from :

$$U_{blade} = (\pi.\ D.\ N) / 60$$

Where: N is the RPM of the wheel.
Available water power:

$$P_{water} = ½ . \rho . A. (V_{water})^3 \qquad \text{(Watt)}$$

Where ρ is density of water (Kg/m^3)
V_{water} = the velocity of water (m/sec)
A = cross section area of blade (m^2)
Waterwheel power:

$$P_1 = (T \times \omega) . \eta \qquad \text{(Watt)}$$

T = torsion load given to the waterwheel shaft (Nm). ω = wheel peripheral velocity (rad/sec)
ω = $2\pi N/60$ (rad/sec)
Waterwheel coefficient of performance::

$$C_p = P_1/P_{water}$$

The same method is also applied for the previous measurements [4]

RESULTS

From the experiments and the collected data, we can plot in such below graphics. The test results, shows that at the water current of 0.9 m/sec the efficiency of 16 blades arrangement shows the best

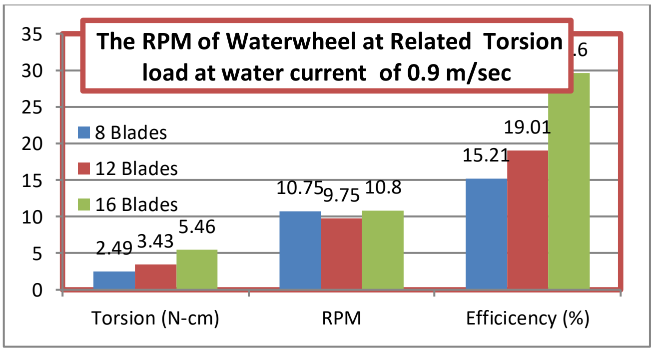

Figure 5. The RPM of waterwheel at related torsion load at water current of 0.9 m/sec

performance where the RPM consistently high.

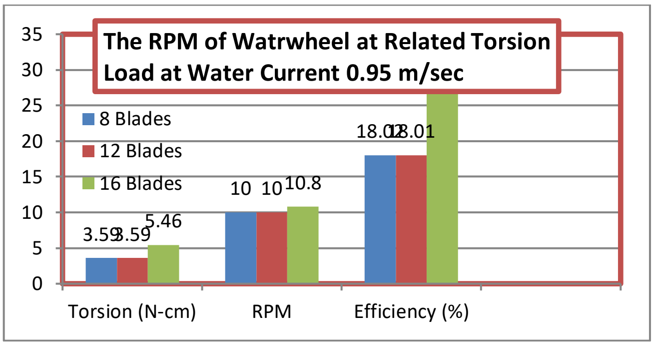

Figure 6. The RPM of waterwheel at related torsion load at water current of 0.95 m/sec

At the speed of current 0.95 m/sec the 16 Blades arrangement shows the best performance. The RPM and the efficiency tend to increase significantly.

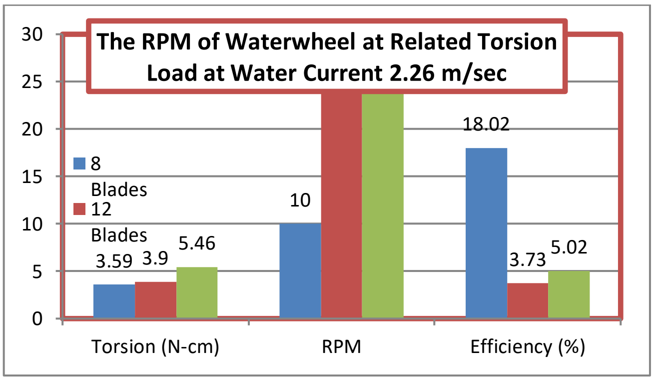

Figure 7. The RPM of waterwheel at related torsion load at water current of 2.26 m/sec

At the speed of current of 2.26 m/sec the waterwheel of 12 Blades show the better performance. Where the RPM is higher than other. The graph shows that at the speed 2.26 m/sec the overall efficiency of waterwheel with 12 Blades and 16 Blades show decrease. However, the waterwheel with 12 and 16 blades show better performance in general. The overall efficiency significantly change at high discharge related to the changing of water level in the channel at corresponding speed. From this point of view, we can conclude that for the wheel diameter of 58 cm, the better performance is showed by 12 Blades and 16 Blades.

The goal of this experiments is idetifying the better number of blades around the wheel circumference for undershot waterwheel of 58 cm diameter. By knowing the best number of blades at the circumference of wheel, we can determine the ratio of pitch to diameter.

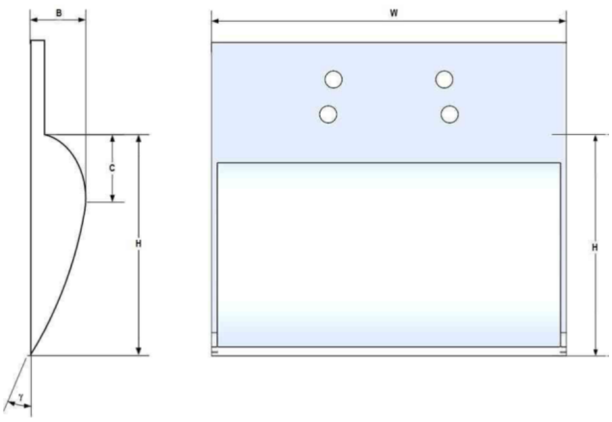

Figure 8. Scoop Blade of gamma angle 10 degree

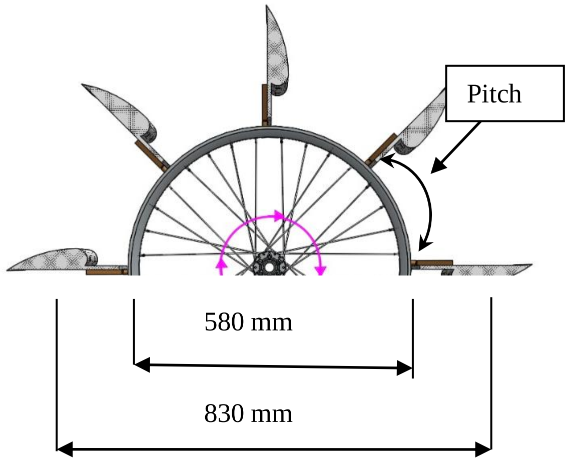

Figure 9. Diameter of wheel and pitch of blades

The ratio of pitch to diameter is required as a benchmark value in designing the waterwheel in real installation. From the above discussion, we can withdraw some conclusions i.e.: The size of Scoop Blade need to be specified regarding its relation to the diameter of wheel. According to the test results, the best number of Scoop Blade of gamma 10 degrees, is lying between 12 and 16 blades. In this case, for the wheel diameter of 58 cm the length of wheel circumference is: π. D = 3.14 x 58 cm = 182.12 cm. So the best pitch value for this case is lying between:

$$\frac{182,12}{12} = 15,176 \quad \text{and} \quad \frac{182,12}{16} = 11,382.$$

From the above value, we can find the ratio of Pitch to Diameter as follows:

$$\frac{Pitch}{Diameter} = \frac{15,176}{58} = 0.261.$$

we get: ***Pitch = 0.261 Diameter***

$$\frac{Pitch}{Diameter} = \frac{11,382}{58} = 0.1962\ .$$

we get ***Pitch = 0.1962 Diameter***

From above calculation, we can conclude that the Pitch of waterwheel blade is :

Pitch = (0.1962 – 0.261) Diameter

The pitch is lying on between (0,1962 – 0.261) of the diameter. The specified value is the results of compromise between technical, economical and the experience.

CONCLUSION

From the experiments results and the discussion above, we can withdraw the following conclusions:

1. The previous tests indicating that the flat blades not fully accomodating the power from the water
2. The effective pitch of blade regarding its relationship to the diameter is:
   Pitch = (0.1962 – 0.261) Diameter
3. It is required to examine the effectivity of Scoop Blade in absorbing the water energy regarding the long and the wide side, and its relation to the diameter of the wheel.

ACKNOWLEDGEMENT

Thanks very much to the Engineering Faculty of Sriwijaya University for financing this research. Thanks also delivered to the final year students involved in the research activity. May this paper presenting a useful matters for the world.

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Submission date: 07-Oct-2021 02:51PM (UTC+0700)
Submission ID: 1667609016
File name: Siceto_revised_article1.docx (459.48K)
Word count: 2830
Character count: 14713

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THE PROBLEM

From the previous experiments [3][4], it already get the effective shape of blade and the angle of gamma of the blade. To complete the research, we now want to determine the relation between diameter of wheel and the distance between the blades. We call it pitch.

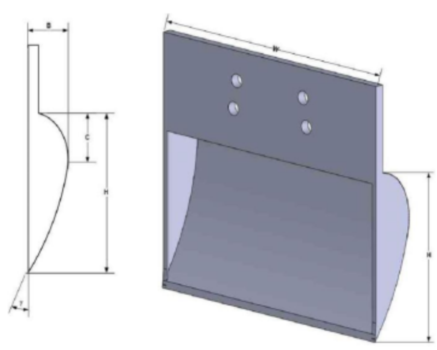

Figure 1. Scoop Blade for low current river waterwheel. [6][7]

A series of tests have been carried out to find the best 'pitch' of Scoop Blade when attached to the waterwheel of 580 mm diameter. The variable of test are the blade number around the circumference of wheel evaluated at varying speed of water. Each of blade number arrangements is evaluated at the corresponding the RPM and the power generated.

METHOD OF EXPERIMENT

The cross section area of blades facing the water current perpendicularly is (10x10) cm or equal to 100 cm^2.All blades attached on the wheel circumference were made of wood of the same shape and the same sizes. All surface of blades were painted.

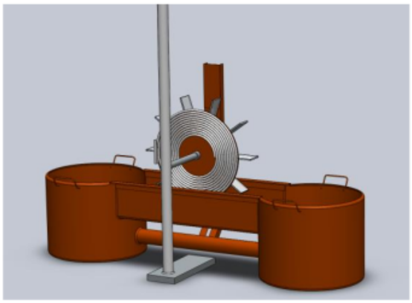

Figure 2. The test aparatus where water circulated by an immersion pump.

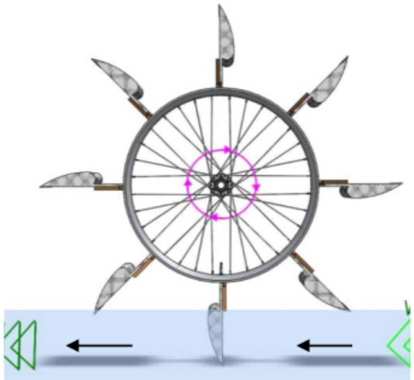

Figure 3. Eight Scoop Blades mounted on tested wheel

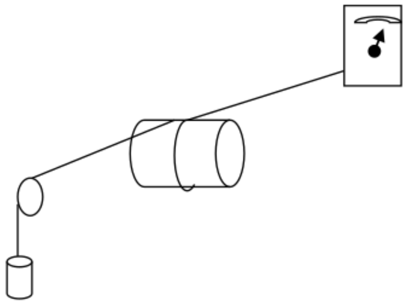

Figure 4. Torsion measurement system on the waterwheel shaft
1.Load balance. 2.Wheel shaft
3.Roll supporting the load rope 4.Load

The revolution per minute (RPM) of the wheel is counted virtually and noted on every torsion loading of the wheel shaft. The peripheral velocity of the wheel is calculated from :

$$U_{blade} = (\pi.\ D.\ N) / 60$$

Where: N is the RPM of the wheel.

Available water power:

$$P_{water} = ½ .\ \rho.A.\ (V_{water})^3 \qquad \text{(Watt)}$$

Where ρ is density of water (Kg/m^3)

V_{water} = the velocity of water (m/sec)

A = cross section area of blade (m^2)

Waterwheel power:

$$P_l = (T \times \omega)\ .\ \eta \qquad \text{(Watt)}$$

T = torsion load given to the waterwheel shaft (Nm). ω = wheel peripheral velocity (rad/sec)

ω = $2\pi N/60$ (rad/sec)

Waterwheel coefficient of performance::

$$C_p = P_l/P_{water}$$

The same method is also applied for the previous measurements [4]

RESULTS

From the experiments and the collected data, we can plot in such below graphics. The test results, shows that at the water current of 0.9 m/sec the efficiency of 16 blades arrangement shows the best

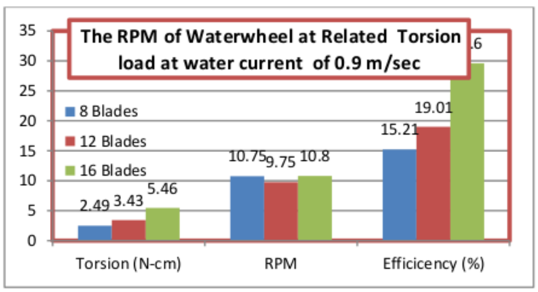

Figure 5. The RPM of waterwheel at related torsion load at water current of 0.9 m/sec

performance where the RPM consistently high.

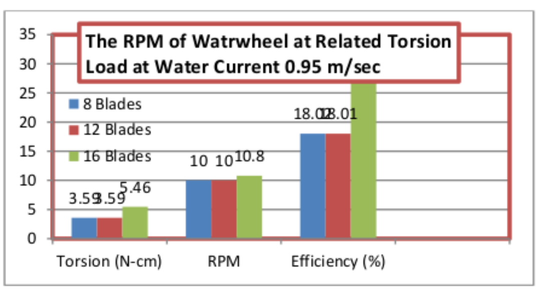

Figure 6. The RPM of waterwheel at related torsion load at water current of 0.95 m/sec

At the speed of current 0.95 m/sec the 16 Blades arrangement shows the best performance. The RPM and the efficiency tend to increase significantly.

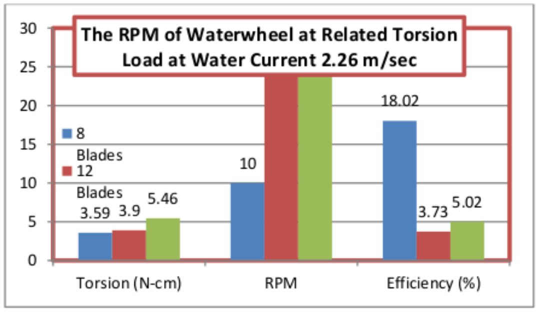

Figure 7. The RPM of waterwheel at related torsion load at water current of 2.26 m/sec

At the speed of current of 2.26 m/sec the waterwheel of 12 Blades show the better performance.
Where the RPM is higher than other. The graph shows that at the speed 2.26 m/sec the overall efficiency of waterwheel with 12 Blades and 16 Blades show decrease. However, the waterwheel with 12 and 16 blades show better performance in general. The overall efficiency significantly change at high discharge related to the changing of water level in the channel at corresponding speed. From this point of view, we can conclude that for the wheel diameter of 58 cm, the better performance is showed by 12 Blades and 16 Blades.

The goal of this experiments is idetifying the better number of blades around the wheel circumference for undershot waterwheel of 58 cm diameter. By knowing the best number of blades at the circumference of wheel, we can determine the ratio of pitch to diameter.

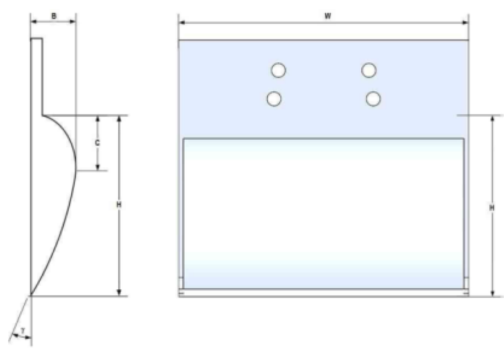

Figure 8. Scoop Blade of gamma angle 10 degree

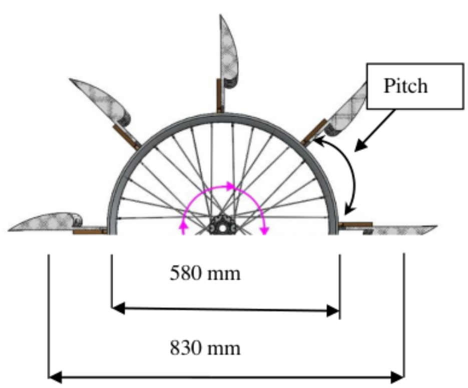

Figure 9. Diameter of wheel and pitch of blades

The ratio of pitch to diameter is required as a benchmark value in designing the waterwheel in real installation. From the above discussion, we can withdraw some conclusions i.e.: The size of Scoop Blade need to be specified regarding its relation to the diameter of wheel. According to the test results, the best number of Scoop Blade of gamma 10 degrees, is lying [8] between 12 and 16 blades. In this case, for the wheel diameter of 58 cm the length of wheel circumference is: π. D = 3.14 x 58 cm = 182.12 cm. So the best pitch value for this case is lying between:

$$\frac{182{,}12}{12} = 15{,}176 \quad \text{and} \quad \frac{182{,}12}{16} = 11{,}382.$$

From the above value, we can find the ratio of Pitch to Diameter as follows:

$$\frac{Pitch}{Diameter} = \frac{15{,}176}{58} = 0.261.$$

we get: ***Pitch = 0.261 Diameter***

$$\frac{Pitch}{Diameter} = \frac{11{,}382}{58} = 0.1962\ .$$

we get ***Pitch = 0.1962 Diameter***

From above calculation, we can conclude that the Pitch of waterwheel blade is :

Pitch = (0.1962 – 0.261) Diameter

The pitch is lying on between (0,1962 – 0.261) of the diameter. The specified value is the results of compromise between technical, economical and the experience.

CONCLUSION

From the experiments results and the discussion above, we can withdraw the following conclusions:

1. The previous tests indicating that the flat blades not fully accomodating the power from the water
2. The effective pitch of blade regarding its relationship to the diameter is:
   Pitch = (0.1962 – 0.261) Diameter
3. It is required to examine the effectivity of Scoop Blade in absorbing the water energy regarding the long and the wide side, and its relation to the diameter of the wheel.

ACKNOWLEDGEMENT

Thanks very much to the Engineering Faculty of Sriwijaya University for financing this research. Thanks also delivered to the final year students involved in the research activity. May this paper presenting a useful matters for the world.

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