http://jurnal.unmer.ac.id/index.php/jtmt
TRANSMISI
ISSN (print): 9-772580-228020
ISSN (online): 2580-2283

# Strength Analysis of Horizontal Type Wind Turbine Blades Using PVC Pipe Material

Radik Kemala Ali, Jumiad Jumiadi*

*Department of Mechanical Engineering, Faculty of Engineering, University of Merdeka Malang*
*Jl. Terusan Dieng No. 62-64 Klojen, Pisang Candi, Sukun, Malang, 65146, East Java, Indonesia.*
**Corresponding author email: jumiadi@unmer.ac.id*

**ARTICLE INFORMATION**

Received: 20 July 2022
Revised: 10 August 2022
Accepted: 25 August 2022
Published: 15 September 2022

**ABSTRACT**

The wind defines as air moves from one place to another which produces kinetic energy. Wind moves due to pressure differences that affect the temperature in a region on the earth's surface. The utilization of wind turbines as the renewable energy is not maximal. This research was focused on understanding the strength of wind turbine spoons which using PVC pipe material. The tensile test was conducted on 5 specimens that used 1 type of PVC and different variations in wind velocity ranging from 3 m/s -7 m/s and the results showed that specimen 1 with wind velocity of 3 m/s was 18.30 kg/mm$^2$, specimen 2 with wind velocity of 4 m/s was 19.32 kg/mm$^2$, specimen 3 with wind velocity of 5 m/s was 21.28 kg/mm$^2$, specimen 4 with wind velocity of 6 m/s was 22.01 kg/mm$^2$, and specimen 5 with wind velocity of 7 m/s was 19.32 kg/mm$^2$.

*Keywords: Wind Turbine, Propeller, Power, Velocity*

**ABSTRAK**

Angin memiliki pengertian udara yang bergerak berpindah dari satu tempat ke tempat lain yang menghasilkan energi kinetik. Angin bergerak akibat adanya perbedaan tekanan yang mempengaruhi pada temperatur di suatu wilayah pada permukaan bumi.penggunaan turbin angin guna medapatkan energi baru masih belum maksimal di karenakan belum ada pemanfaatan energi tersebut. Pada penelitian tugas akhir ini ini di fokuskan untuk mengetahui kekuatan sudu turbin angin menggunakan bahan pipa pvc. Untuk mengetahui nya di lakukan uji Tarik sebanyak 5 spesimen dengan menggunakan 1 jenis pvc dan menggunakan variasi kecepatan angin yang berbeda mulai 3m/s -7m/s dan hasil yang di dapatkan setelah pengujian Tarik pada specimen 1 menggunakan kecepatann angin sebesar 3 m/s tegangan yang terjadi sebesar 18,30 kg/mm$^2$, specimen 2 menggunakan kecepatan angin sebesar 4 m/s tegangan yang terjadi sebesar 19,32 kg/mm$^2$ , specimen 3 menggunakan kecepatan 5 m/s tegangan yang terjadi sebesar 21,28, kg/mm$^2$ , specimen 4 menggunakan kecepatan angin sebesar 6 m/s tegangan yang terjadi sebesar 22,01 kg/mm$^2$ , specimen 5 menggunakan kecepatan angin sebesar 7 m/s tegangan yang terjadi sebesar 19,32 kg/mm$^2$

DOI: 10.26905/jtmt.v18i2.9206

Kata Kunci: Turbin Angin, Baling-baling, Kekuatan Kecepatan



## 1. Introduction

The availability of energy in Indonesia is increasing over time, but this is inversely proportional to the availability and production of that energy [1]. The problem that we must overcome now is the diminishing supply of fossil fuels that can be processed into fossil fuels as the main energy source [2]. Anticipating the occurrence of a scarcity of fossil energy in Indonesia, it is necessary to create new ideas or ideas to reduce consumption of fossil energy but diverted to the use of new and renewable energy (EBT) which has very abundant potential in Indonesia, but its use has not been utilized optimally by public [3]. In the midst of this energy crisis, efforts are needed to find the best solution considering that energy is one of the basic needs in society. Sectoral Energy Needs that are not yet efficient such as household, transportation, industry, commercial. In the future, we must maximize the supply and utilization of renewable energy as a counterweight [3]. Why are new energy and renewable energy being developed, because the existence of fossil energy (BBM, Gas, Coal) is categorized as limited, Fossil energy cannot be relied upon as the main energy source in driving future economic growth, Fossil energy produces emissions that can damage the environment, Indonesia has very abundant sources of renewable energy. Renewable energy sources can be a mainstay of Indonesia's energy sources in an environmentally friendly future [4].

Alternative efforts made to overcome this energy scarcity include converting energy from kinetic energy to electrical energy by means of creating a wind turbine. One of the accessories is the propeller/blade. The function of the blade is to change the momentum of a fluid that hits the blade which is then developed as a thrust [5].

The materials used for this wind turbine include ferrous and non-ferrous metals, the division of which is ferrous metal found in shafts, bearings, rotors, wind turbine handles for non-ferrous materials found on the rotor cover, turbine blades. Therefore, it can be known the strength or fatigue of the turbine blades by means of a Tensile test in the Tensile test later it can be known that the mechanical properties of the test specimen from the test can be known the level of Tensile strength or elasticity of the test specimen.

## 2. Methodology of Research

This field study aims to anticipate if there is a depletion of fossil energy in Indonesia by utilizing alternative energy, namely wind energy through wind turbines and using experimental research methods carried out at the Mechanical Engineering Achievement Test Laboratory, Faculty of Engineering, University of Merdeka Malang. In carrying out field studies, the authors took data from wind tunnel test machines and test objects using a three-blade wind turbine with variations in wind velocity and the results are:

a. Rotor rotation (Rpm) generated for each test
b. Voltage (Volt) generated for each test
c. Current (Amperes) generated each test

*2.1 Research parameter*

There are 2 types of parameters in this field study, which are:

1. Dependent variables
   a. Turbine blade tensile strength
   b. Turbine blade voltage.
2. Independent variables
   a. PVC pipe materials
   b. Three total spoons

*2.2 Design of test objects*

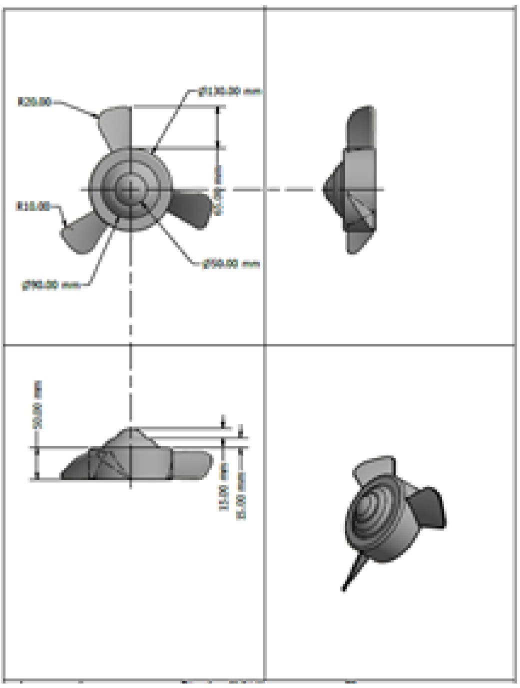

**Figure 1.** Three-blade wind turbine design

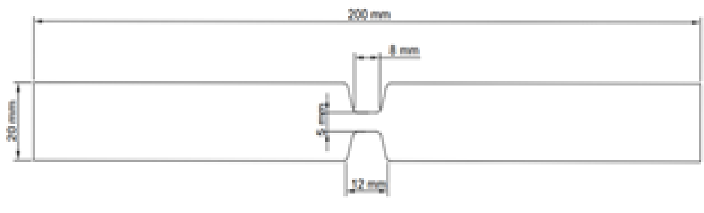


**Figure 2.** Tensile test specimen

## 3. Result and Discussion

The research results can be presented with a table showing the results of the research.

**Table 1** Retrieval of initial test data

| No | Material | Lo (mm) | bo (mm) | to (mm) | Lf (mm) | Ao ($mm^2$) | Pmax (Kg) |
|---|---|---|---|---|---|---|---|
| 1 | PVC 1 | 8.2 | 5.7 | 2.3 | 16 | 13.11 | 240 |
| 2 | PVC 2 | 7.5 | 5.4 | 2.3 | 13.5 | 12.42 | 240 |
| 3 | PVC 3 | 8.1 | 4.8 | 2.3 | 12.7 | 11.04 | 235 |
| 4 | PVC 4 | 8.6 | 4.8 | 2.3 | 16 | 11.04 | 243 |
| 5 | PVC 5 | 8 | 5.4 | 2.3 | 14.4 | 12.42 | 240 |

Information:
Lo = Initial length
$b_{o}$ = Initial width
$t_o$= Initial thickness
$L_f$ = Final length

*3.1 Calculation of Tensile Test Data*

Calculation of length increment:
$\Delta L = L_f - Lo$
$= 16 - 8{,}2$
$= 7{,}8$ mm
Based on the graph obtained ΔL=40 mm
Thus, each mm = $\frac{\Delta L1}{\Delta L} = \frac{7{,}8}{40} = 0{,}195$
ΔL on the graph can be shown as 4 parts as follows:
$\Delta L_1 = 3 \times 0{,}195 = 0{,}59$ mm
$\Delta L_2 = 6 \times 0{,}195 = 4{,}17$ mm
$\Delta L_3 = 20 \times 0{,}195 = 3{,}90$ mm
$\Delta L_4 = 40 \times 0{,}195 = 7{,}80$ mm

The load received from the specimen from the measuring tool of the Tensile testing machine is a maximum load of 240.00 kgf on the Tensile test chart.

$$P = \frac{240}{52} = 4{,}62\ kgf$$

Thus = $P_1 = 31 \times 4{,}62 = 143{,}08$ kgf
$P_2 = 45 \times 4{,}62 = 207{,}69$ kgf
$P_3 = 51 \times 4{,}62 = 235{,}38$ kgf
$P_4 = 52 \times 4{,}62 = 240{,}00$ kgf

Technical stress

$$\sigma 1 = \frac{P1}{Ao}$$

Where Ao = 13,11 mm

Thus : $\sigma_1 = \frac{143{,}08}{13{,}11} = 10{,}91$ kgf/$mm^2$
$\sigma_2 = \frac{207{,}69}{13{,}11} = 15{,}84$ kgf/$mm^2$
$\sigma_3 = \frac{235{,}38}{13{,}11} = 17{,}95$ kgf/$mm^2$
$\sigma 4 = \frac{240{,}00}{13{,}11} = 18{,}30$ kgf/$mm^2$

Technical strain

$$e = \frac{\Delta L}{L_0} \times 100\%$$

Where : Lo = 8,2 mm

Thus : $e_1 = \frac{0{,}59}{8{,}2} \times 100\% = 7{,}13\%$
$e_2 = \frac{1{,}17}{8{,}2} \times 100\% = 14{,}27\%$
$e_3 = \frac{3{,}90}{8{,}2} \times 100\% = 47{,}27\%$
$e_4 = \frac{7{,}80}{8{,}2} \times 100\% = 95{,}56\%$

Actual stress
Uniform deformation (plastic)

$$\sigma_s = \sigma\,(1 + \varepsilon)$$

Thus:
$\sigma s_1 = 10{,}91\,(1 + 1{,}07) = 11{,}69$ kgf/$mm^2$
$\sigma s_2 = 15{,}84\,(1 + 1{,}14) = 18{,}10$ kgf/$mm^2$
$\sigma s_3 = 17{,}95\,(1 + 1{,}48) = 26{,}49$ kgf/$mm^2$
$\sigma s_4 = 18{,}30\,(1 + 1{,}95) = 35{,}72$ kgf/$mm^2$

Actual strain

$$\varepsilon = \ln(1 + e)$$

Thus: $\varepsilon_1 = \ln(1+0{,}07) \times 100\% = 6{,}89\ \%$
$\varepsilon_2 = \ln(1+1{,}14) \times 100\% = 13{,}34\ \%$
$\varepsilon_3 = \ln(1+1{,}48) \times 100\% = 38{,}91\ \%$
$\varepsilon_4 = \ln(1+1{,}95) \times 100\% = 66{,}85\ \%$

for further calculations calculated in the same way can be tabled as follows:

**Table 2** Recapitulation of Calculation Results

| No. | Specimen | ΔL (mm) | P (kgf) | σ (kgf/$mm^2$) | ε (%) | σs (kgf/$mm^2$) | ε (%) |
|---|---|---|---|---|---|---|---|
| 1 | PVC 1 | 0.59 | 143.08 | 10.91 | 7.13 | 11.69 | 6.89 |
| | | 4.17 | 207.69 | 15.84 | 14.27 | 18.10 | 13.34 |
| | | 3.90 | 235.38 | 17.95 | 47.27 | 26.49 | 38.91 |
| | | 7.80 | 240.00 | 18.30 | 95.56 | 35.72 | 66.85 |
| 2 | PVC 2 | 0.19 | 110.77 | 8.91 | 7.50 | 9.14 | 2.47 |
| | | 0.56 | 175.38 | 14.12 | 14.70 | 15.18 | 7.23 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| | | 2.63 | 216.92 | 17.46 | 35.00 | 23.58 | 30.1 |
| | | 6.00 | 240.00 | 19.32 | 80.00 | 34.78 | 58.78 |
| 3 | PVC 3 | 0.19 | 161.27 | 14.60 | 2,47 | 14.14 | 2.44 |
| | | 0.56 | 198.14 | 17.94 | 7.41 | 19.28 | 7.15 |
| | | 2.63 | 225.79 | 20.45 | 14.81 | 23.48 | 13.82 |
| | | 6.00 | 235.00 | 21.28 | 56.79 | 33.37 | 44.97 |
| 4 | PVC 4 | 0.23 | 139.27 | 12.63 | 2.69 | 12.98 | 2.65 |
| | | 0.93 | 207.00 | 18.75 | 10.76 | 22.77 | 10.22 |
| | | 3.47 | 234.00 | 21.19 | 40.35 | 29.74 | 33.89 |
| | | 7.40 | 243.00 | 22.01 | 86.05 | 40.95 | 62.08 |
| 5 | PVC 5 | 0.19 | 184.62 | 14.86 | 2.42 | 15.22 | 2.40 |
| | | 0.78 | 221.54 | 17.83 | 9.70 | 19.57 | 9.26 |
| | | 3.30 | 230.77 | 18.58 | 41.21 | 26.24 | 34.51 |
| | | 6.40 | 240.00 | 19.32 | 80.00 | 34.78 | 58.78 |

After calculating with the above method, the technical stress and strain graph appears as below:

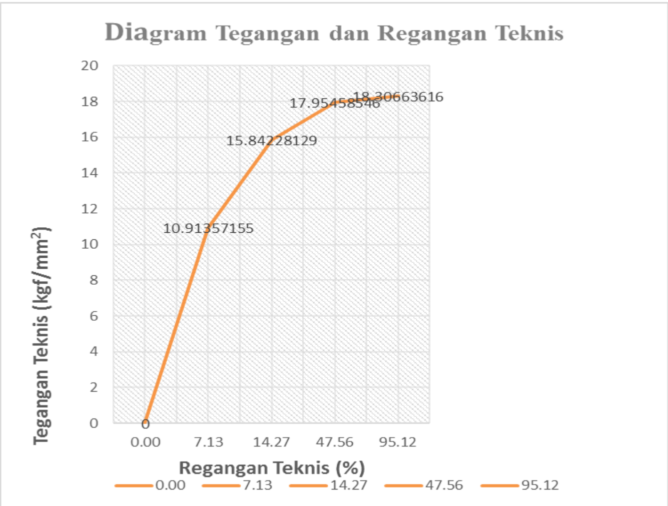


**Figure 3** Stress and Strain Diagram

According to the Figure 3 it can be seen that the technical stress and strain values at the time of testing Tensile max technical stress or at point 4 is 18.30 and the strain that occurs is 95.12%, namely at point 1 it has a technical stress of 10.91 kgf/mm2 which can be look at the chart above and it has a technical strain value of 7.13% and can be connected so that it can form a straight line down

*3.2 Torque Analysis of Blades*

Blade width (b)=70 mm

Blade thickness (t)= 2,3 mm

Blade cross sectional area

$(A_0)$ = b x t

=70 x 2,3 = 161 $mm^2$

**$P_{electrical}$ (Electrical Power)**

$P_l$ = I x V

= 0,88 Ax 0,00262 V

= 0,00231 Watt

Where:

I = Electric current (Ampere)

V = Voltage (Volt)

**Wind Power**

$P_{wind} = \frac{1}{2} \times \rho \times V^3 \times A$

$= \frac{1}{2} \times 1{,}09\ kg/m^3 \times (3\ m/s)^3 \times 0{,}053\ m^2$

= 0,7798 watt

**Where:**

ρ = Air density ($kg/m^3$)..

V = Wind velocity (m/s)

A = Blade cross sectional area = $\pi/4 \times D^2$

$\frac{\pi}{4} \times (0{,}26\ m)^2$

= 0,053 $m^2$

**D = Blade Diameter (260 mm)= 0,26 m**

ω = 2 x π x n/60

$= \frac{2 \times 3{,}14 \times 250{,}53}{60}$

= 26,16 rad/s

n = Roatation 250,53 (rpm) put/rad

The torque received by the blades

P wind= T x ω

T = P wind/ ω

$= \frac{0,7798 \text{ watt}}{26,22 \text{ put/rad}}$

= 0,0297 Nm

$F = \frac{T}{R}$

$= \frac{0,6128 \text{ Nm}}{0,013 \text{ m}}$

F = 2,284 N = $\frac{2,284 \text{ kgm/s2}}{9,81 \text{ m/s2}}$ =0,2328 kgf

(The force received by the blades).

With the same method on all test specimens can be tabled as follows:

**Table 3** The Calculation Result of Blades Torque

| No | Wind Velocity V(mm/s) | Motor Rotation (Rpm) | Torque (Kg) |
|---|---|---|---|
| 1 | 3 | 250,53 | 0,2328 |
| 2 | 4 | 391,30 | 0,3543 |
| 3 | 5 | 520,03 | 0,5402 |
| 4 | 6 | 580.23 | 0,8053 |
| 5 | 7 | 650.42 | 1,1406 |

After getting the rotary force and cross-sectional area, then we calculate the stress that occurs in the propeller blade, namely:

Ơ = torque/blade cross-sectional area

= 0.2328 kg/161mm$^2$

= 0,001446 kg/mm$^2$

With the same calculation method, it can be tabled as follows:

**Table 4** Calculation results of the propeller blade stress and calculation of the stress from the propeller blade tensile test.

| No | Specimen | Wind Velocity V (mm/s) | Motor Rotation (rpm) | Torque (kg) | Maximum Force During Test (kg) | Stress on Blades (kg/mm$^2$) | Stress on Tensile Test (kg/mm$^2$) | Information |
|---|---|---|---|---|---|---|---|---|
| 1 | PVC 1 | 3 | 250.53 | 0.2328 | 143.08 | 0.001446 | 18.30 | Safe |
| 2 | PVC 2 | 4 | 391.3 | 0.3543 | 110.77 | 0.002200 | 19.32 | Safe |
| 3 | PVC 3 | 5 | 520.03 | 0.5402 | 161.27 | 0.003355 | 21.28 | Safe |
| 4 | PVC 4 | 6 | 580.03 | 0.8053 | 139.27 | 0.00500 | 22.01 | Safe |
| 5 | PVC 5 | 7 | 650.42 | 11.406 | 185.62 | 0.00708 | 19.32 | Safe |

Based on the table above, it can be seen that the safety of the propeller while running, for example, can be seen in specimen 1 with a velocity of 3 m/s at a motor rotation velocity of 250.53 rpm and the force obtained when testing the material with a tensile test of 143.08 kg has a rotating force of 0.2328 kg. From table 3.4 it is known that the stress that occurs in the propeller when a rotation occurs is 0.001446 kg/mm2, while from the results of testing the propeller material it is obtained at 18.30 kg/mm2. Thus, because the stress that occurs in the propeller is smaller than the stress possessed by the material, it can be concluded that the propeller material used is declared safe.

## 4. Conclusion

Based on the results of the research that has been done, the following conclusions can be drawn, the rotational force that occurs at the propeller blades by conducting seven experiments obtains a maximum rotational force of 1.1406 kg. Based on the test results using five test samples, the smallest stress was obtained, namely 18.30 kg/mm2. The highest stress that occurs on the turbine blade is 0.00708 kg/mm2, while the stress that occurs on the lowest propeller blade material is 18.30 kg/mm2, thus the stress that occurs on the blade during rotation is smaller than the tensile strength of the material. turbine blades, so that it is in a safe condition.

## Reference


[1] N. Nugroho and S. Agustina, “Analisa Motor DC (Direct Current) sebagai Penggerak Mobil Listrik,” *Mikrotiga*, vol. 2, no. 1, pp. 28–34, 2015.

[2] S. Sinaga and H. Pranoto, “Analisis Kebutuhan Energi Motor Listrik pada Mobil Hybrid Urban KMHE 2018,” *J. Tek.*, vol. 09, no. 3, 2020.

[3] V. N. Setiawan, “Proyeksi Energi: Pandemi Covid-19 Percepat Peralihan ke Energi Hijau,” *katadata.co.id*, 2021. https://katadata.co.id/sortatobing/ekonomi-hijau/5f6067d5e9382/proyeksi-energi-pandemi-covid-19-percepat-peralihan-ke-energi-hijau.

[4] X. cong ZHONG, B. ZHANG, Z. cong LIN, J. ming LIU, Y. min XIE, and Z. feng XU, “Preparation and performance of 3D-Pb anodes for nonferrous metals electrowinning in H2SO4 aqueous solution,” *Trans. Nonferrous Met. Soc. China (English Ed.*, vol. 30, no.

2, pp. 535–547, 2020, doi: 10.1016/S1003-6326(20)65233-5.

[5] E. Novita and H. Ahmad, “Teknologi Pengering Efek Rumah Kaca Sebagai Sumber Energi Alternatif Bangunan Pengering Hasil Pertanian,” *Lemb. Pengabdi. pada Masy. Univ. Jember*, 2013.