Data Article

Dataset of Comprehensive Thermal Performance on Cooling the Hot Tube Surfaces of Vortex Tube at Different Pressure and Fraction

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A B S T R A C T

The performance of the vortex tube is low compared to a conventional heat pump engine based on Freon refrigerants, and therefore, there is a need for an experiment on how to improve its efficiency. This data article aims to analyze the effect of the new vortex tube design on cold temperature ($T_c$), hot temperature ($T_h$), delta cold temperature ($\Delta T_c$), delta hot temperature ($\Delta T_h$), heat transferred as cooling effect ($Q_c$), heat transferred as heating effect ($Q_h$), isentropic efficiency as cooling effect ($\eta_{isc}$), isentropic efficiency as heating effect ($\eta_{ish}$), the coefficient of performance refrigeration (COP$_{ref}$), and coefficient of performance heat pump (COP$_h$), which is tested based on pressure and fraction variations. The data were obtained from the experimental measurements. Data were collected at conditions with temperature controlled at $27 \pm 0.1^\circ C$. All measuring instruments were supposed to be consistent for at least 5 min for data to be collected, although retrieval was conducted 4 times.

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Specifications Table

| Subject                      | Engineering, Mechanical Engineering |
|------------------------------|--------------------------------------|
| Specific subject area        | Heat transfer, Fluid dynamics, Thermodynamics, Heat and mass transfer, Thermophysical property measurement, Cryogenics, Counter-flow Ranque-Hilsch Vortex Tube, Heat Pump. |
| Type of data                 | Table Image                          |
| How data were acquired       | Figure                               |
| Data format                  | Raw Data                              |
| Parameters for data collection | The parameters for experimental data include the temperature of the air to the inlet, room air, air from hot and cold outlets, and water to the cooling tube. It also included the volume of the airflow rate to the inlet, the pressure of the air entering the channel to the inlet, maximum air velocity from cold outlet, testing air velocity of nth-testing from cold outlet, and cooling water flow rate volume. |
| Description of data collection | Data were collected based on the conditions of the test chamber, whose temperature was controlled at 27 ± 0.1°C. The data were taken in case all measuring instruments were consistent at least 5 minutes. Data Retrieval was carried out 4 times. |
| Data source location         | Department of Mechanical Engineering Education, Universitas Sebelas Maret City/Town/Region: Central Java Province Country: Indonesia |
| Data accessibility           | With the article                     |
| Related research article     | Sarifudin, A., Wijayanto, D.S., Widiastuti, I, Parameters optimization of tube type, pressure, and mass fraction on vortex tube performance using the Taguchi method. International Journal of Heat and Technology, [https://doi.org/10.18280/ijht.370230](https://doi.org/10.18280/ijht.370230) |

Value of the data

- The data describes comprehensive RHVT thermal performance on the new vortex tube design tested based on pressure and fraction variations.
- The data illustrates the design specifications of the new vortex tube design to improve their performance.
- The data describes the installation procedures and working specifications of the measuring instruments to determine the performance on the vortex tube.
- The data provides calculation procedures for mathematical analysis of the experimental measurement.

1. Data Description

The performance of the vortex tube is low compared to a conventional heat pump engine based on Freon refrigerants, and therefore, there is a need for an experiment on how to improve its efficiency. Furthermore, the vortex tube has several benefits, including no moving parts or mechanical wear, saving maintenance costs, no Freon use, and it is environmentally friendly [1,2]. According to previous studies, the parameters that might improve its performance include mass fraction, air pressure entering the inlet, material type, and geometry [3–7]. This experiment, therefore, aims to determine the best vortex tube performance parameters tested under variations in design, pressure and fraction. The performance dataset presented includes cold temperature ($T_c$), hot temperature ($T_h$), delta cold temperature ($\Delta T_c$), delta hot
Table 1  
Temperature average air exits from the natural cooling vortex tube cold outlet.

| Cold air mass fraction | Air pressure to inlet |
|------------------------|-----------------------|
|                        | 0.5bar     | 1.0bar    | 1.5bar    |
| 30%                    | 21.650°C  | 18.250°C  | 15.850°C  |
| 40%                    | 21.100°C  | 17.350°C  | 14.925°C  |
| 50%                    | 21.900°C  | 18.650°C  | 16.375°C  |
| 60%                    | 22.350°C  | 19.375°C  | 17.300°C  |
| 70%                    | 22.825°C  | 20.175°C  | 18.350°C  |

Table 2  
Temperature of the mean air exit from the vortex tube cold outlet and forced cooling.

| Cold air mass fraction | Air pressure to inlet |
|------------------------|-----------------------|
|                        | 0.5bar     | 1.0bar    | 1.5bar    |
| 30%                    | 20.600°C  | 16.600°C  | 13.950°C  |
| 40%                    | 20.200°C  | 16.050°C  | 13.450°C  |
| 50%                    | 20.400°C  | 16.450°C  | 14.000°C  |
| 60%                    | 20.600°C  | 16.850°C  | 14.575°C  |
| 70%                    | 20.975°C  | 17.875°C  | 15.925°C  |

Table 3  
Temperature average air exits from the natural cooling vortex tube heat outlet.

| Cold air mass fraction | Air pressure to inlet |
|------------------------|-----------------------|
|                        | 0.5bar     | 1.0bar    | 1.5bar    |
| 30%                    | 29.300°C  | 30.075°C  | 30.500°C  |
| 40%                    | 30.550°C  | 31.800°C  | 32.550°C  |
| 50%                    | 32.500°C  | 35.050°C  | 36.650°C  |
| 60%                    | 34.900°C  | 38.975°C  | 41.000°C  |
| 70%                    | 32.500°C  | 35.750°C  | 37.850°C  |

Table 4  
Temperature of the mean air exit from the vortex tube heat outlet and forcible cooling.

| Cold air mass fraction | Air pressure to inlet |
|------------------------|-----------------------|
|                        | 0.5bar     | 1.0bar    | 1.5bar    |
| 30%                    | 27.400°C  | 27.550°C  | 27.650°C  |
| 40%                    | 28.025°C  | 28.575°C  | 28.975°C  |
| 50%                    | 28.325°C  | 29.050°C  | 29.600°C  |
| 60%                    | 28.575°C  | 29.550°C  | 30.250°C  |
| 70%                    | 28.050°C  | 28.650°C  | 29.050°C  |

temperature($\Delta T_h$), heat transferred as cooling effect ($\dot{Q}_c$), heat transferred a heating effect ($\dot{Q}_h$), isentropic efficiency as cooling effect ($\eta_{isc}$), isentropic efficiency as heating effect ($\eta_{ish}$), coefficient of performance refrigeration ($COP_{ref}$), and coefficient of performance heat pump ($COP_h$).

The average temperature of cold air produced by vortex tubes with natural cooling tube types is presented in Table 1 while Table 2 shows the vortex tubes with forced cooling. Temperature data are presented using °C units.

The average temperature of hot air produced by vortex tubes with natural cooling tube types is presented in Table 3, while Table 4 shows the vortex tubes with forced cooling. Temperature data are presented using °C units.
Table 5
Average changes in the cold temperature of air coming out of the natural cooling vortex tube cooling outlet.

| Cold air mass fraction | Air pressure to inlet |
|------------------------|-----------------------|
|                        | 0.5bar | 1.0bar | 1.5bar |
| 30%                    | 5.350°C | 8.750°C | 11.150°C |
| 40%                    | 5.900°C | 9.650°C | 12.075°C |
| 50%                    | 5.100°C | 8.350°C | 10.625°C |
| 60%                    | 4.650°C | 7.625°C | 9.700°C  |
| 70%                    | 4.175°C | 6.825°C | 8.650°C  |

Table 6
Changes in the cold temperature mean air exits from the vortex tube cold forced cooling outlet.

| Cold air mass fraction | Air pressure to inlet |
|------------------------|-----------------------|
|                        | 0.5bar | 1.0bar | 1.5bar |
| 30%                    | 6.400°C | 10.400°C | 13.050°C |
| 40%                    | 6.800°C | 10.950°C | 13.550°C |
| 50%                    | 6.600°C | 10.550°C | 13.000°C |
| 60%                    | 6.400°C | 10.150°C | 12.425°C |
| 70%                    | 6.025°C | 9.325°C  | 11.075°C |

Table 7
Changes temperature average air exits from the natural cooling vortex tube heat outlet.

| Cold air mass fraction | Air pressure to inlet |
|------------------------|-----------------------|
|                        | 0.5bar | 1.0bar | 1.5bar |
| 30%                    | 2.300°C | 3.075°C | 3.500°C |
| 40%                    | 3.550°C | 4.800°C | 5.550°C |
| 50%                    | 5.500°C | 8.050°C | 9.650°C |
| 60%                    | 7.900°C | 11.975°C | 14.000°C |
| 70%                    | 5.500°C | 8.750°C  | 10.850°C |

Table 8
Changes temperature of the mean air exit from the vortex tube heat outlet and forcible cooling.

| Cold air mass fraction | Air pressure to inlet |
|------------------------|-----------------------|
|                        | 0.5bar | 1.0bar | 1.5bar |
| 30%                    | 0.400°C | 0.550°C | 0.650°C |
| 40%                    | 1.025°C | 1.575°C | 1.975°C |
| 50%                    | 1.325°C | 2.050°C | 2.600°C |
| 60%                    | 1.575°C | 2.550°C | 3.250°C |
| 70%                    | 1.050°C | 1.650°C | 2.050°C |

Changes in the cold ($\Delta T_c$) or hot air temperature ($\Delta T_h$) is the difference in inlet temperature ($T_i$) to cold outlet temperature ($T_c$) or hot outlet temperature ($T_h$), as shown in equation [8]

\[ \Delta T_c = T_i - T_c \] (1)

\[ \Delta T_h = T_h - T_i \] (2)

The changes in the cold temperature ($\Delta T_c$) of cold air produced by vortex tubes with natural cooling tube types is presented in Table 5 while Table 6 shows the vortex tubes with forced cooling. Temperature data are presented using °C units.

The hot air temperature ($\Delta T_h$) of hot air produced by vortex tubes with natural cooling tube types is presented in Table 7 while Table 8 shows the vortex tubes with forced cooling. Temperature data are presented using °C units.
Table 9
Temperature change in the isentropic process of air enter into of the vortex tube inlet.

| Cold air mass fraction | Air pressure to inlet 0.5bar | 1.0bar | 1.5bar |
|------------------------|-------------------------------|--------|--------|
| 30%                    | 16.39%                        | 16.30% | 16.19% |
| 40%                    | 18.08%                        | 17.98% | 17.53% |
| 50%                    | 15.63%                        | 15.56% | 15.43% |
| 60%                    | 14.25%                        | 14.21% | 14.08% |
| 70%                    | 12.79%                        | 12.71% | 12.56% |

Table 10
Average Isentropic Efficiency of air coming out of the natural cooling vortex tube cooling outlet.

| Cold air mass fraction | Air pressure to inlet 0.5bar | 1.0bar | 1.5bar |
|------------------------|-------------------------------|--------|--------|
| 30%                    | 16.39%                        | 16.30% | 16.19% |
| 40%                    | 18.08%                        | 17.98% | 17.53% |
| 50%                    | 15.63%                        | 15.56% | 15.43% |
| 60%                    | 14.25%                        | 14.21% | 14.08% |
| 70%                    | 12.79%                        | 12.71% | 12.56% |

The temperature change in the isentropic process ($\Delta T_{is}$) is calculated by the following equation [8]

$$\Delta T_{is} = T_i \left(1 - \left(\frac{P_a}{P_i}\right)^{\gamma-1} \right)$$  (3)

Where the specific heat ratio ($\gamma$) is the specific heat at constant pressure ($C_p$) per specific heat at constant volume ($C_v$) [9]. Based on the Cengel table appendix 1 (2006) for this ambient experiment the constant pressure ($C_p$) is 1.007kJ/kg.K and constant volume ($C_v$) is 0.7180kJ/kg.K [9]:

$$\gamma = \frac{C_p}{C_v}$$  (4)

Temperature change in the isentropic process ($\Delta T_{is}$) produced by vortex tubes with natural cooling and forced cooling tube types is presented in Table 9 shows the vortex tubes with forced cooling. Temperature data are presented using °C units.

Isentropic Efficiency ($\eta_{is}$) is the sum of the changes in the inlet to outlet temperature at each isentropic temperature change, as shown in the following equation [8]:

$$\eta_{is} = \frac{\Delta T}{\Delta T_{is}}$$  (5)

The cold outlet isentropic efficiency ($\eta_{isc}$) and hot outlet isentropic efficiency ($\eta_{ish}$) equations are shown by the following:

$$\eta_{isc} = \frac{T_i - T_c}{T_i \left(1 - \left(\frac{P_a}{P_i}\right)^{\gamma-1} \right)}$$  (6)

$$\eta_{ish} = \frac{T_h - T_i}{T_i \left(1 - \left(\frac{P_a}{P_i}\right)^{\gamma-1} \right)}$$  (7)

The Cold Isentropic Efficiency ($\eta_{isc}$) of cold air produced by vortex tubes with natural cooling tube types is presented in Table 10 while Table 11 shows the vortex tubes with forced cooling. An isentropic Efficiency is a dimensionless number, expressed as a percentage number.

The Hot Isentropic Efficiency ($\eta_{ish}$) of hot air produced by vortex tubes with natural cooling tube types is presented in Table 12 while Table 13 shows the vortex tubes with forced cooling.
Table 11
Isentropic Efficiency mean air exits from the vortex tube cold forced cooling outlet.

| Cold air mass fraction | Air pressure to inlet | 0.5bar | 1.0bar | 1.5bar |
|------------------------|-----------------------|--------|--------|--------|
| 30%                    | 19.61%                | 19.38% | 18.95% |
| 40%                    | 20.84%                | 20.40% | 19.67% |
| 50%                    | 20.22%                | 19.65% | 18.87% |
| 60%                    | 19.61%                | 18.91% | 18.04% |
| 70%                    | 18.46%                | 17.37% | 16.08% |

Table 12
Hot Isentropic Efficiency exits from the natural cooling vortex tube heat outlet.

| Cold air mass fraction | Air pressure to inlet | 0.5bar | 1.0bar | 1.5bar |
|------------------------|-----------------------|--------|--------|--------|
| 30%                    | 7.05%                 | 5.73%  | 5.08%  |
| 40%                    | 10.88%                | 8.94%  | 8.06%  |
| 50%                    | 16.85%                | 15.00% | 14.01% |
| 60%                    | 24.21%                | 22.31% | 20.33% |
| 70%                    | 16.85%                | 16.30% | 15.75% |

Table 13
Hot Isentropic Efficiency exits from the vortex tube heat outlet and forcible cooling.

| Cold air mass fraction | Air pressure to inlet | 0.5bar | 1.0bar | 1.5bar |
|------------------------|-----------------------|--------|--------|--------|
| 30%                    | 1.23%                 | 1.02%  | 0.94%  |
| 40%                    | 3.14%                 | 2.93%  | 2.87%  |
| 50%                    | 4.06%                 | 3.82%  | 3.77%  |
| 60%                    | 4.83%                 | 4.75%  | 4.72%  |
| 70%                    | 3.22%                 | 3.07%  | 2.98%  |

The fraction ($ε_c$) of the cold outlet was obtained from the speed of the mass flow of air coming out, specifically $m_{out}$ at each mass flow rate of air entering the inlet $m_{in}$. In Eq. (8), each air mass flow was measured at the same diameter and air pressure to obtain a simplified Eq. (9). In general, where $v_{cn}$ is the speed of air coming out at the cold outlet on n-variable tested and $v_{cmax}$ is the maximum mass flow rate of air coming out of the cold outlet with the heat outlet tightly closed. This is meant to satisfy the law of mass balance, which states that the mass coming out of the system is the same as the mass entering the system. The formulas to adjust the size of the fraction are as follows [2,3]

$$ε_c = \frac{m_{out,c}}{m_{in}}$$  (8)

$$ε_c = \frac{v_{c,n}}{v_{c,max}}$$  (9)

Maximum wind speed comes out of the cold outlet for each pressure is 0.5bar (8.4$m_{in}$), 1.0bar (11.2$m_{in}$), and 1.5bar (14.0$m_{in}$). The regulation of the air velocity for each fraction is carried out by playing the valve gap in the hot outlet, then presented in Table 14.

The value of the volume flow rate ($V_{in}$) for each pressure is presented in Table 15 and presented in units of $m^3/s$.

Based on the Cengel table appendix 1 (2006) the value of gas constant ($R$) is 0.2870$kfl/kg.K$ [9]. The gas density ($\rho$) equation is described as:

$$\rho = \frac{P_{in,absolute}}{RT}$$  (10)
Table 14
Air velocity exits the cold outlet.

| Cold air mass fraction | Air pressure to inlet |
|------------------------|-----------------------|
|                        | 0.5bar | 1.0bar | 1.5bar |
| 30%                    | 2.5$m_1$/s | 3.4$m_1$/s | 4.2$m_1$/s |
| 40%                    | 3.4$m_1$/s | 4.5$m_1$/s | 5.6$m_1$/s |
| 50%                    | 4.2$m_1$/s | 5.6$m_1$/s | 7.0$m_1$/s |
| 60%                    | 5.0$m_1$/s | 6.7$m_1$/s | 8.4$m_1$/s |
| 70%                    | 5.9$m_1$/s | 7.8$m_1$/s | 9.8$m_1$/s |

Table 15
The rate of volume flow to the inlet.

| Air pressure to inlet | 0.5bar | 1.0bar | 1.5bar |
|-----------------------|--------|--------|--------|
| 0.137029395$m^3$/s   | 0.252419435$m^3$/s | 0.420141149$m^3$/s |

Table 16
The density flow to the inlet.

| Air pressure to inlet | 0.5bar | 1.0bar | 1.5bar |
|-----------------------|--------|--------|--------|
| $P_{in, absolute}$    | (151.335Pa) | (201.335Pa) | (251.335Pa) |
| Gas Density           | 0.137029395$kg/m^3$ | 0.252419435$kg/m^3$ | 0.420141149$kg/m^3$ |

Table 17
Mass flow to the inlet.

| Air pressure to inlet | 0.5bar | 1.0bar | 1.5bar |
|-----------------------|--------|--------|--------|
| 0.137$kg_S$           | 0.252$kg_S$ | 0.420$kg_S$ |

Table 18
Mass flow exits from the cold outlet.

| Cold air mass fraction | Air pressure to inlet |
|------------------------|-----------------------|
|                        | 0.5bar | 1.0bar | 1.5bar |
| 30%                    | 0.041$kg_S$ | 0.076$kg_S$ | 0.126$kg_S$ |
| 40%                    | 0.055$kg_S$ | 0.101$kg_S$ | 0.168$kg_S$ |
| 50%                    | 0.069$kg_S$ | 0.128$kg_S$ | 0.216$kg_S$ |
| 60%                    | 0.082$kg_S$ | 0.151$kg_S$ | 0.252$kg_S$ |
| 70%                    | 0.096$kg_S$ | 0.177$kg_S$ | 0.294$kg_S$ |

Ambient gas temperature, used in Kelvin units, is 300.15K. The value of $\rho$ in the following Table 16 is presented in units of $kg/m^3$.

The mass flow rate flowing at the hot outlet is denoted as $\dot{m}_{outh}$. The $Cp$ value can be determined by reading the table while $T$ is the temperature of the air coming into through the hot outlet.

According to the equilibrium equation, the mass flow rate formula is as follows [2,10]

$$\dot{m}_{in} = \dot{m}_{outc} + \dot{m}_{outh}$$  (11)
Table 19
Mass flow exits from the hot outlet.

| Cold air mass fraction | Air pressure to inlet |
|------------------------|-----------------------|
|                        | 0.5bar                | 1.0bar | 1.5bar |
| 30%                    | 0.096 kg/s            | 0.177 kg/s | 0.294 kg/s |
| 40%                    | 0.082 kg/s            | 0.151 kg/s | 0.252 kg/s |
| 50%                    | 0.069 kg/s            | 0.126 kg/s | 0.210 kg/s |
| 60%                    | 0.055 kg/s            | 0.101 kg/s | 0.168 kg/s |
| 70%                    | 0.041 kg/s            | 0.076 kg/s | 0.126 kg/s |

Table 20
Heat flow rate at cold outlet on natural cooling RHVT.

| Cold air mass fraction | Air pressure to inlet |
|------------------------|-----------------------|
|                        | 0.5bar                | 1.0bar | 1.5bar |
| 30%                    | 0.221 kJ/s            | 0.667 kJ/s | 1.415 kJ/s |
| 40%                    | 0.326 kJ/s            | 1.061 kJ/s | 2.248 kJ/s |
| 50%                    | 0.352 kJ/s            | 1.636 kJ/s | 2.462 kJ/s |
| 60%                    | 0.385 kJ/s            | 1.214 kJ/s | 2.560 kJ/s |
| 70%                    | 0.403 kJ/s            | 1.214 kJ/s | 2.560 kJ/s |

Table 21
Heat flow rate at cold outlet on force cooling RHVT.

| Cold air mass fraction | Air pressure to inlet |
|------------------------|-----------------------|
|                        | 0.5bar                | 1.0bar | 1.5bar |
| 30%                    | 0.265 kJ/s            | 0.793 kJ/s | 1.656 kJ/s |
| 40%                    | 0.375 kJ/s            | 1.113 kJ/s | 2.293 kJ/s |
| 50%                    | 0.455 kJ/s            | 1.341 kJ/s | 2.750 kJ/s |
| 60%                    | 0.530 kJ/s            | 1.548 kJ/s | 3.154 kJ/s |
| 70%                    | 0.582 kJ/s            | 1.657 kJ/s | 3.280 kJ/s |

Table 22
Heat flow rate at hot outlet on natural cooling RHVT.

| Cold air mass fraction | Air pressure to inlet |
|------------------------|-----------------------|
|                        | 0.5bar                | 1.0bar | 1.5bar |
| 30%                    | 0.222 kJ/s            | 0.547 kJ/s | 1.032 kJ/s |
| 40%                    | 0.294 kJ/s            | 0.732 kJ/s | 1.409 kJ/s |
| 50%                    | 0.379 kJ/s            | 1.023 kJ/s | 2.041 kJ/s |
| 60%                    | 0.436 kJ/s            | 1.216 kJ/s | 2.369 kJ/s |
| 70%                    | 0.228 kJ/s            | 0.667 kJ/s | 1.377 kJ/s |

Table 23
Heat flow rate at hot outlet on force cooling RHVT.

| Cold air mass fraction | Air pressure to inlet |
|------------------------|-----------------------|
|                        | 0.5bar                | 1.0bar | 1.5bar |
| 30%                    | 0.039 kJ/s            | 0.098 kJ/s | 0.193 kJ/s |
| 40%                    | 0.085 kJ/s            | 0.240 kJ/s | 0.501 kJ/s |
| 50%                    | 0.091 kJ/s            | 0.261 kJ/s | 0.550 kJ/s |
| 60%                    | 0.087 kJ/s            | 0.259 kJ/s | 0.550 kJ/s |
| 70%                    | 0.043 kJ/s            | 0.126 kJ/s | 0.260 kJ/s |
Table 24
Total compressed air power entering the inlet.

| Air pressure to inlet | 0.5bar | 1.0bar | 1.5bar |
|-----------------------|--------|--------|--------|
|                       | 4.734kJ/s | 14.928kJ/s | 32.875kJ/s |

Where \( \dot{m}_{in} \) is the air mass flow entering, while \( \dot{m}_{outh} \) is the air mass flow coming out through the hot outlet. From Eq. (5), these variables are proportional in the inlet vortex tube. Since the instrument can only measure air conditions at the inlet and the cold outlet, \( \dot{m}_{outh} \) could be determined through the use of the equation.

The value of the incoming mass flow on the vortex tube is [2]

\[
\dot{m}_{in} = V_{in} \rho \quad (12)
\]

The mass flow that enters the inlet (\( \dot{m}_{in} \)) for each pressure in the Table 17 is presented in units of \( \text{kg/s} \).

Mass flow at cold outlet (\( \dot{m}_{outc,n} \)) that occur at the \( n \)th cold fraction (\( \varepsilon_{cn} \)) is denoted by the following equation:

\[
\dot{m}_{outc,n} = \dot{m}_{in} \times \varepsilon_{c,n} \quad (13)
\]

Mass flow out through the cold outlet in the Table 18 \( \dot{m}_{outc} \) is presented in the following table in unit \( \text{kg/s} \).

Refer to Eq. 11, the mass flow through the hot outlet (\( \dot{m}_{outh,n} \)) that occur at the \( n \)th cold fraction (\( \varepsilon_{cn} \)) is denoted by the following equation:

\[
\dot{m}_{outh,n} = \dot{m}_{in} - \dot{m}_{outh,n} \quad (14)
\]

Mass flow out through the hot outlet \( \dot{m}_{outh} \) is presented in the Table 19 in unit \( \text{kg/s} \).

The amount of heat that can be transferred by the vortex tube as a cooling effect is denoted as \( Q_c \). It is obtained using the following equation [2,3,11,12]:

\[
Q_c = \dot{m}_{outc} \cdot C_p \cdot (T_c - T_{in}) \quad (15)
\]

Where \( \dot{m}_{outc} \) is the air mass flowing every second at the cold outlet, \( C_p \) is the capacity of air at ambient during the test, \( T_c \) is the value of the air temperature through the cold outlet, and \( T_{in} \) is the temperature of the air entering the inlet vortex tube. The \( T_c \) and \( T_{in} \) values were obtained from the data measured.

The Table 20 dan Table 21 present the heat flow rate for cold outlet in \( \text{kJ/s} \).

The amount of heat transferred by the vortex tube as a heating effect is denoted by \( \dot{Q}_h \) and obtained using the following equation [13]:

\[
\dot{Q}_h = \dot{m}_{outh} \cdot C_p \cdot (T_h - T_{in}) \quad (16)
\]

The mass flow rate flowing at the hot outlet is denoted as \( \dot{m}_{outh} \). The \( C_p \) value can be determined by reading the table while \( T \) is the temperature of the air coming into through the hot outlet. The Table 22 and Table 23 present the heat flow rate for hot outlet in \( \text{kJ/s} \).

The total compressed air power entering the inlet with ideal isothermal compression is as follows [3,6,7,13–15]:

\[
W = \dot{m}_{in} \cdot R \cdot T_{in} \cdot \ln \left( \frac{P_{in}}{P_{atm}} \right) \quad (17)
\]

From Eq. (17), \( \dot{m}_{in} \) is the mass flow rate of air entering the inlet channel, \( R \) is the specific gas constant, \( T_{in} \) is the temperature of the air, and \( P_{in} \) is the air pressure entering the inlet channel. The environmental air pressure is denoted by \( P_{atm} \). The Table 24 presents the total compressed air power entering the inlet in \( \text{kJ/s} \).
Table 25
COP_{ref} average air exits from the natural vortex tube cold cooling outlet.

| Cold air mass fraction | Air pressure to inlet |
|------------------------|-----------------------|
|                        | 0.5bar | 1.0bar | 1.5bar |
| 30%                    | 0.047  | 0.046  | 0.044  |
| 40%                    | 0.069  | 0.068  | 0.062  |
| 50%                    | 0.074  | 0.074  | 0.070  |
| 60%                    | 0.081  | 0.081  | 0.079  |
| 70%                    | 0.085  | 0.083  | 0.083  |

Table 26
COP_{ref} the mean air coming out of the vortex cold tube forced cooling outlet.

| Cold air mass fraction | Air pressure to inlet |
|------------------------|-----------------------|
|                        | 0.5bar | 1.0bar | 1.5bar |
| 30%                    | 0.056  | 0.054  | 0.050  |
| 40%                    | 0.079  | 0.078  | 0.069  |
| 50%                    | 0.096  | 0.093  | 0.087  |
| 60%                    | 0.112  | 0.104  | 0.097  |
| 70%                    | 0.123  | 0.111  | 0.100  |

Table 27
COP_{h} mean air exit from the vortex tube and cold forced outlet.

| Cold air mass fraction | Air pressure to inlet |
|------------------------|-----------------------|
|                        | 0.5bar | 1.0bar | 1.5bar |
| 30%                    | 0.047  | 0.037  | 0.036  |
| 40%                    | 0.066  | 0.049  | 0.043  |
| 50%                    | 0.080  | 0.068  | 0.062  |
| 60%                    | 0.076  | 0.081  | 0.072  |
| 70%                    | 0.039  | 0.043  | 0.042  |

The coefficient of performance refrigeration (COP_{ref}) is a dimensionless number that measures the performance of a cooling heat pump engine when transferring heat from a cooled room [2,12]. For a vortex tube, it is calculated as follows [2,3,12].

\[
COP_{ref} = \frac{\dot{Q}_c}{\dot{W}}
\]  \hspace{1cm} (18)

The average COP_{ref} produced by vortex tube with natural cooling tube type is presented in Table 25 while the vortex tube with forced cooling is shown in Table 26. COP_{ref} numbers are dimensionless, therefore they are presented without units.

The coefficient of performance heat pumps (COP_{h}) is a dimensionless number that measures the performance of a heat pump engine when transferring heat to a heated chamber [2,12]. It was denoted as follows in the vortex tube [2,3,12].

\[
COP_{h} = \frac{\dot{Q}_h}{\dot{W}}
\]  \hspace{1cm} (19)

Table 27 and 28 shows the average COP_{h} produced by vortex tubes with natural cooling tube types and vortex tubes with forced cooling respectively. There are no dimensions for COP_{h} numbers.

2. Experimental Design, Materials, and Methods

Data collection was carried out through experimental tests and processed mathematically. The RHVTs include types A with a natural cooling process and B with the forced cooling process,
Table 28
COP<sub>n</sub> average air exits from the vortex tube cold forced outlet.

| Cold air mass fraction | Air pressure to inlet |
|------------------------|-----------------------|
|                        | 0.5bar | 1.0bar | 1.5bar |
| 30%                    | 0.008  | 0.007  | 0.006  |
| 40%                    | 0.018  | 0.016  | 0.015  |
| 50%                    | 0.019  | 0.017  | 0.017  |
| 60%                    | 0.018  | 0.017  | 0.017  |
| 70%                    | 0.009  | 0.008  | 0.008  |

Table 29
Experimental devices.

| Initial | Name                              | Function                                      | Symbol | Unit       | Sensitivity values |
|---------|-----------------------------------|-----------------------------------------------|--------|------------|-------------------|
| AC      | Air Conditioner                   | Room temperature controller                   | -      | °Celsius   | 0.1               |
| C       | Compressor                        | Pressurized air supply                       | -      | -          | -                 |
| AT      | Air Tank                          | Maintained air pressure so as not to drop, reduce humidity and return to room temperature | -      | -          | -                 |
| PR      | Pressure Regulator                | Sets the input air pressure                   | -      | -          | -                 |
| PG      | Pressure Gauge                    | Measured inlet air pressure                   | \(P_{in}\) | bar       | 0.1               |
| AFM     | Flowmeter (air)                   | Measured airflow                             | \(V_{in}\) | Liter/min | 0.1               |
| VTA / VTB | Vortex tube (type A and type B)   | Test instrument                               | -      | -          | -                 |
| AM      | Anemometer                        | Measured the speed of cold outlet air         | \(v_{inm}\) and \(v_{inmax}\) | meter/sec | 0.1               |
| TCD     | Thermocouple Display              | Measured hot and cold outlet air temperature  | -      | °Celsius   | 0.01              |
| WCS     | Water Container Storage           | Saved water for cooling                       | -      | -          | -                 |
| WCT     | Water Container Trash             | Saved waste water for cooling                 | -      | -          | -                 |
| P       | Pump                              | Pumped cooling water                          | -      | -          | -                 |
| WFM     | Flowmeter (water)                 | Measured water discharge                      | \(V_{water}\) | Liter/min | 0.1               |
| DA      | Data Acquisition                  | Recorded measurement data                    | -      | -          | -                 |
| PC      | Personal Computer                 | Processed observation data from each measuring instrument | -      | -          | -                 |
| TCS1    | Thermocouple Sensor 1 (Type K)    | Measured the temperature of the inlet air    | \(T_{in}\) | °Celsius   | -                 |
| TCS2    | Thermocouple Sensor 2 (Type K)    | Measured the temperature of the cold outlet air | \(T_{c}\) | °Celsius   | -                 |
| TCS3    | Thermocouple Sensor 3 (Type K)    | Measured the temperature of the hot outlet air | \(T_{h}\) | °Celsius   | -                 |
| TCS4    | Thermocouple Sensor 4 (Type K)    | Measured ambient air temperature              | T      | °Celsius   | -                 |
| TCS5    | Thermocouple Sensor 5 (Type K)    | Measured the temperature of the cooling water air | - | °Celsius   | -                 |

both on the surfaces of the tube. The RHVT used in types A and B was counter flow and the material used in all case was aluminium, except the cooling tube of B which used the black Teflon. The inlet diameter was 5mm, while the cold and hot tube had diameters and lengths 5mm and 40mm as well as 8mm and 105mm respectively. The diameter of the inlet and outlet of the cooling tube on type B RHVT was 8mm. However, an inner tube had a diameter of 25mm and a length of 75mm. Fig. 1 shows the details of the RHVT specifications used.

Types A and B had 4 nozzle holes and the air rotation is in the direction of the flow at the inlet. The nozzle hole is rectangular with dimensions of 1 × 2mm. The diameter of the round
nozzles is 8mm with a thickness of 1.5mm. The detailed specifications of the RHVT contra flow nozzles used are presented in Fig. 2.

Fig. 3 shows a series of instruments used for experimental data collection. In the Left and right sides of the figure are Type A and B vortex tubes respectively. The temperature was set at $27^\circ\pm0.1^\circ$C and data were recorded after 5 minutes of running.

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Conflict of Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Supplementary materials

Supplementary material associated with this article can be found, in the online version, at doi:10.1016/j.dib.2020.105611.

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