DOI: https://doi.org/10.53555/nnmce.v5i2.304 **Publication URL: http://nnpub.org/index.php/MCE/article/view/304**

THROTTLE VALVE AS A HEATING ELEMENT IN WIND HYDRAULIC THERMAL SYSTEM

Muhammad Mujtaba[1]*, Wang Cuntang[2], Faisal Muhammad Yasin[3], Fangwei Xie[4],

[*]School Mechanical Engineering, Jiangsu University, Zhenjiang 212013, China

[*]Corresponding Author: -

Email: *mujtaba.malik332@yahoo.com* Tel:+86 18851409774

Abstract: -

A new energy conversion system is established which converts wind hydraulic energy directly to heat energy. For this purpose of conversion throttle valve considered as a heat generating source in the utilization of wind energy to confine the wind energy into thermal energy. The use of throttle valve indicates to calculate the heat generation by using the simulation in Matlab and count the physical and mathematical model of the heating system. Various analyses are made on the basis of throttle valve parameters to compare the theoretical results on various values. To compute the effective results, needle valve used as a testing element in hydraulic system to change the opening of the throttle valve which estimates the heat generating capacity of the system. The opening degree and angle of the throttle valve are analyzed theoretically under the condition of constant flow rate. The effect of stiffness and other parameters on the heating system analyzed at the same time. The results show that the valve opening is responsible for the generation of the heat as more heat can be achieved in case of the small opening. Another analysis is made that the angle changed on throttle tip significantly affects the heat effect of the throttle valve. To ensure the stability of the system the stiffness of the throttle valve will be more conductive to ensuring a constant pressure across the valve port. The Matlab software is used to build a mathematical model for a proper analysis on throttle valve on various openings to check the pressure drop relationship with different parameters.

Keywords: *hydraulic heating system; throttle needle valve, Pressure drop, stability, simulation*

INTRODUCTION:

Domestic energy consumption attracts the economic resources which are reliable to manage the lack of energy availability in some areas where the wind is powerful and more power can be achieved utilizing these resources in a particular way. The savories wind turbines have the potential to be integrated on the roofs of houses and building and contribute significantly in the reduction of the average house hold electricity costs. The technological improvements of wind turbine are not even quite advanced as commercial wind turbines which contributed to increase the overall power output.[1]Wind hydraulic system is an efficient and noiseless system as in hydraulic system the gear system is eliminated by the hydraulic pump. The hydraulic system is more reliable and cost effective as compare to use the gear system and its maintenance and other overhauling takes too much attention and time to maintain the system performance. [2]Wind energy is a clean and pollution-free renewable energy. Wind energy can be converted into a various kinds of energy forms such as mechanical energy, pressure energy, electric energy and thermal energy. There are many researchers who have done detailed work on wind power generation except a little concentration on directly conversion of wind power to hydraulic heating system. Generally there are two ways to convert wind energy. The first method of energy conversion is direct conversion of wind energy, in which Wind energy is harvest by the wind, then turbine rotor energy is directly converted to mechanical energy which is attached to the hydraulic system and further which is applicable to appear in thermal energy for heating purpose [3].The second method is indirect conversion , in which the conversion of wind to electrical energy then this electric energy can be converted to thermal energy but the efficiency of wind energy conversion energy is very low. Unstable wind energy will cause the fluctuation of electric energy. The direct conversion of wind energy into thermal energy is better form of energy in utilization, equipment cost or the control of complex system. It is more feasible than indirect energy conversion system. In general, there are many ways for direct wind heat generation. The one is heat generation by the stirring of the liquid, second Compressed air heat generation and Due to the friction between solids.[4]. It is easy to install and simple to controls this wind hydraulic heating system. The heat generating element used in hydraulic heating system is throttle orifice. The intermittent characteristics of wind exhibit to use storage as a back to eliminate this effect and consumptive more energy by wind energy[5] To adjust the heating effect in the variable wind speed system throttle valve can be used as a better enhancement of heating. This paper uses a hydraulic wind induced heat generating method which is easy to install and control. The wind heat conversion is carried out by the combination of Hydraulic and orifices. This heating system causes by the throttle valve used in system. A throttle valve is used instead of an orifice to control the thermal efficiency of the system in unsteady wind speed. [6]The idea about the heat generation by throttling depends upon many researches and publication on the throttling devices to have good impact for the reliable sources for throttles to be used in heating system. Despite its frequent use in many petrochemical and transportation engineering applications, the pneumatic transport of dilute solid particles or liquid droplets in gas flow through needle valve has many shortcomings. This is because needle valve introduces a change in flow channel and a change in flow direction, resulting in significant change of flow field.[7] Wind power is harvested using a high-torque low speed turbine. Intermittent wind speed introduces hydraulic flow fluctuations from the prime mover that eventually changes the electric power flow in the system.[8] A parametric study of throttling components in a multi-stage high pressure reducing valve is carried out, including the relative angle of inner and outer porous shrouded holes, the orifice plate thickness, the number of orifice plates and the diameter of plate holes. By [9] Pressure and temperature reducing systems are energy saving devices used to regulate steam parameters, and utilize waste heat in cogeneration and central heating engineering.[10]

1. **Hydraulic wind heating system**

Hydraulic wind heating is a method based on the principle of fluid throttling effect and frictional heat generation, and uses the hydraulic system and throttling device to generate heat, so as to transform the energy of wind energy, mechanical energy, hydraulic energy and heat energy. The wind heating conversion part adopts hydraulic damping wind energy direct heating type, in which a range of wind energy density are absorbed by wind turbine, and converted into pressure energy of hydraulic oil through a hydraulic pump, the high pressure hydraulic oil flow through a narrow damping throttle orifice which can reduce pressure and control mass flow rate by changing the section area or length of orifice [2]. The hydraulic oil bearing high pressure and low velocity ejected to throttle orifice by the circulating pipes, which action to Discharge at high speed while remaining in throttle orifice to modify its properties in a sense of pressure and velocity. The velocity would be reach to at a normal desire speed and decrease in pressure while passing through orifice. The process of energy conversion is that the pressure energy of hydraulic fluid is first transformed into liquid kinetic energy, and then there will be great pressure loss due to the friction and sudden orifice impact. In a result of this conversion there will be a loss in pressure and the fluid state changes by pressure energy to thermal energy, while the temperature of the fluid tends to increase in high value. Most of these losses are converted into thermal energy, resulting in the increase of oil temperature. The heating element throttle valve in the system is equivalent to the thermal performance of the heat generation in the wind power system, which determines the heat efficiency of the system. Therefore, the key to ensure the thermal stability and efficiency of the system is to choose the proper size of the throttle valve and to match the hydraulic pump. Figure 1 reflects the main demonstration about Domestic hydraulic heating system.

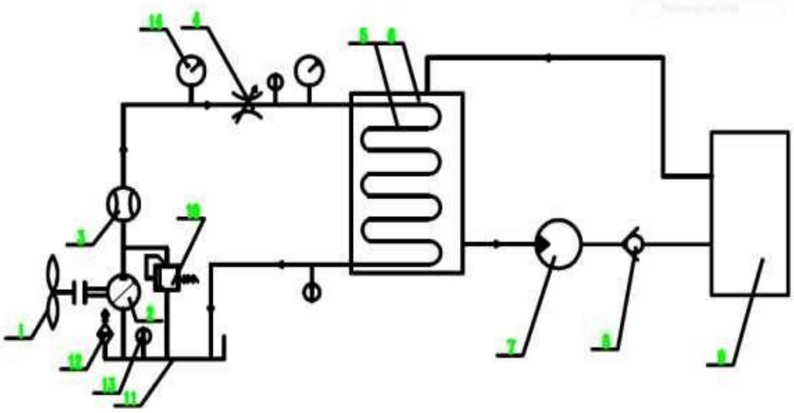

Figure 1 Domestic wind hydraulic heating system.

1. Wind turbine 2. Displacement Pump 3.Flow meter 4.throttle valve 5.heat exchanger 6. Insulated Hot Water storage tank 7. Hot water Delivery Pump 8. Check valve 9. Radiator 10. Pressure Relief valve 11. Oil reservoir 12. Oil filter 13.temperature sensor 14. Pressure gauge

The working principle of the wind turbine starts from the rotation of the rotor blades of the wind blades which rotates due to the angular affect of the wind. The power harvested by the wind turbine drives the hydraulic pump at a high velocity up to the hydraulic pump runs at high revolutions. The low pressure oil is sucked by the hydraulic pump and which increases the pressure of oil to a high pressurized energy. This high pressurized hydraulic oil is then allowed to enter to throttle orifice and due to the violent impact of the throttle valve as a resisting element, there will be a molecular collision between the oil particles.[11] The high pressurized oil energy is converted to thermal energy of the oil. There will be a pressure drop and velocity enhancement while the oil flowing through the throttle valve at a constant discharge. The hot oil enters to the heat exchange coils and leaves its heat to the water tank and cold oil again return back to the oil reservoir. This water tank is used as storage to overcome the intermittent of the wind power and it can be used in unavailability of the wind. A temperature rise will take place by circulating the heated oil during a specific interval of time which is used to heat the environment.[12]. It is an established fact that heat is generated in a fixed displacement hydraulic system whenever fluid is throttled from high pressure to low pressure without doing any work. This generated heat is normally taken as a measure of system efficiency[13] In our system the source of generation of heat is the Needle throttle valve which is used to enhance the characteristics of the heat generation. This article express the more utilization of wind energy in such a way that the turns of the throttle valve will eliminate the intermittent characteristics of the wind generation to declare more Energy by the use of the throttle turns into to a particular direction. . To analyze the system there are three appearances has been made in this article.

1) In the case of constant flow, the throttle opening changes its pressure across the valve port impact
2) Influence of Needle Valve number of turns with respect to time on feasible Heating System ;
3) The purpose of storage used in our system to enhance the backup for the heat supply to our house in absence of the wind.

Methodology and model analysis of heating system

1. Model analysis

The demonstration between the main components in the system model is shown in Figure 1. When the wind is insufficient, the water tank storage can be used as a backup and it can be used to provide enough heating for the household when the power is less.

2. Thermal principle of system

The analysis of the heating property of the system is mainly based on the pressure drop and opening of the throttle valve for the heat generating capacity. The theoretical analysis shows the demonstration of the heating process. It can be verified that according to Bernoulli's law, the sum of various forms of energies at the inlet of throttle valve is equal to the sum of all forms of energy at outlet taking the oil mass in a unit [14]

$$\frac{Po}{\rho} + gh_1 + \frac{1}{2}a_1 v_1{}^2 = \frac{P_1}{\rho} + gh_2 + \frac{1}{2}a_2 v_2{}^2 + gh_w \quad \textbf{(1)}$$

In the formula, Po and P_1 are the inlet and outlet pressure of the throttle valve, ρ is the oil density is,$_1$ and v_2 are the flow velocities at inlet and outlet. h_1 and $_2$ are the heads of the fluid at the inlet and outlet, h_w is the energy loss flowing through the throttle valve.AS we know that Flow continuity equation: $\rho_1 A_1 v_1 = \rho_2 A_2 v_2$

Assume that the fluid is no compressibility so the value for $\rho_1 = \rho_2$ so $A_1 = A_2$ and $v_1 = v_2$. Considered that the fluid flow only in horizontal direction so the head is the same for system thus

$$h1 = h2 \quad (2)$$

From Eq. (1) ~ Eq. (2), it is noted that:

$$\Delta P = \rho g h$$

$$h_w = \frac{\Delta P}{\rho g}$$

So further

Therefore, the fluid pressure difference is the major component which is responsible for the energy losses in throttle orifice. The main focus of research is mainly directed to the pressure difference in fluid flowing through throttling valve. However, according to the law of conservation of energy, these energy losses can only be converted into thermal energy without considering heat transfer.
So, heat production:

$$\Delta Q = \rho g h_w q = \Delta P q \qquad (4)$$

In the case of the same flow and the same aperture, the pressure difference flow characteristics of the throttle valve can be compared. Flow pressure difference equation for valve port is expressed through this equation:

$$q = C_d A_o \sqrt{2\Delta P/\rho} \qquad (5)$$

In the formula q discharge through orifice, C_d is the Discharge coefficient for needle valve used in system, A is the area corresponds to flow, ρ is the density of fluid used, ΔP is the differential pressure by the throttle valve. In throttle flow there are two parts which are under concentration. One part of the fluid flow is prior to the throttle or needle port. The other part is the throttle port or needle itself at where the differential flow occurs due to the action b the needle of the orifice. The displacement of the needle valve is about to 10mm maximum flow through needle valve. So for each part the flow is different due to its structure. The discharge through orifice can be expressed by these equations:

$$q_1 = C_d A_1 \sqrt{2\Delta P_1}/\rho \qquad \text{For inlet} \qquad (6)$$

$$q_2 = C_d A_2 \, sin\alpha \sqrt{2\Delta P_2}/\rho \qquad \text{for needle port} \qquad (7)$$

The various analysis made by Matlab for the use of proper orifice to generate heat for the system. Matlab results exhibit the perfect selection of the throttle valve to emphasize the efficient heating system. Differential pressure flow characteristic curve compared with various displacements shows the perfectly selection of a throttle valve for a particular module under the same flow rate and the same opening. By the modification of equation 5 we can get this differential such as:

$$\Delta P_1 = \frac{\rho}{2}\left(\frac{q}{C_d A_1}\right)^2 \qquad \text{(Inlet)} \qquad (8)$$

$$\Delta P_2 = \frac{\rho}{2}\left(\frac{q}{C_d A_2 sin\alpha}\right)^2 \qquad \text{Throttle port} \qquad (9)$$

According to the expressions 7 & 8 it is noted that'd' is the diameter of inlet and throttle ports which is same in both conditions but the area is different for both ports which are shown in above equations. The term x shows the displacement opening by the throttle valve in vertical direction, α is the angle shown in figure.3, the liquid viscosity is denoted by'μ' and the value of oil viscosity is $\mu = 1500 \times 10^{-4}\ N\cdot s/m2$ .When the valve opening decreases from 0.8 to 0.6and 0.4, the pressure drop become very large. This is due to the flow rate increases with the reduction of valve opening.[7] Small changes in the opening and angle of the valve port will significantly affect the pressure difference between the throttle valve orifices. The pressure difference between the two ends of the throttle valve port is affected by the opening and angle of the valve port. A slight change in the angle will significantly affect the heat effect of the throttle valve. In order to get the total pressure difference by throttle the both pressure differential can be calculated and further final result will be total pressure difference created by the throttle port by both port. So the total pressure drop ΔP will be by the inlet and throttle ports as it can be written as $\Delta P = \Delta P_1 + \Delta P_2$. It is observed that a large amount of pressure drop causes when the flow passing through the needle valve center. The pressure across the inlet is about to uniform flow when the fluid stream passes through the valve, which is after reached to a needle port adjustable area and the maximum pressure measured around the needle tip on the occurrence at stagnation point. The results about the flow pressure difference on throttle valve port characteristic curves under different pressure and discharge in the presence of various changing in throttle valve displacement are acquired according to the equation.8 and 9 which is analyzed by the Matlab. The simulation results validation shows the characteristics curve of throttling valve, when the throttle valve starts working the pressure noted to be about 1Mpa and throttling valve cause some resistant while closing its opening to a minimum displacement. The simulation is shown in figure.1 and 2 verify the pressure drop by the throttle valve under different opening.

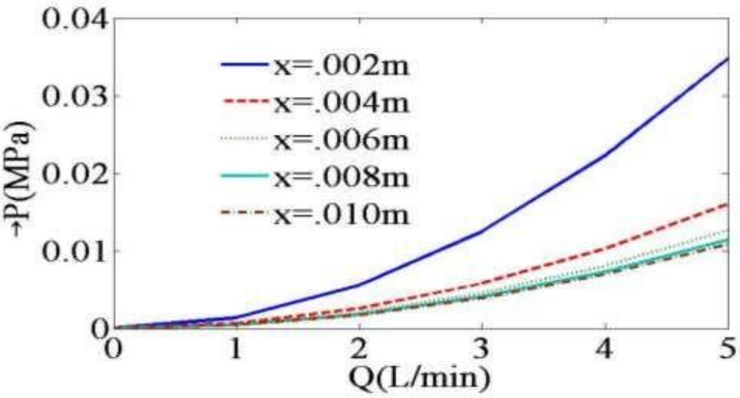

Figure.2 Flow and pressure difference characteristic curve of the throttle valve

The above analysis indicates that it is easy to conceive that with the increase in flow rate, the pressure difference between the two ends of throttle valve is also increases as shown in figure.2. At the beginning stage, differential pressure created by the throttle valve is very little and it contribute more changes in pressure drop when the discharge increase and the value opening decreases about to 4mm of throttle orifice. The equation.4 shows that the heat production effect of the system is determined by the pressure difference, which indicates that the thermal performance increasing rapidly when the valve opening is very small. However, because of the large stiffness of the throttle valve based on the valve port, it is not conducive to ensure the stability of the pressure difference at the front and rear ends of the valve port which is influenced by the flow rate. Therefore, in wind hydraulic heating system, a particular valve opening is chosen opening which is used to reduce the flow pulsation of the pump according to the actual working condition. In order to improve the stability of the system heat supply a proper valve port opening is better for the proper enhancement of the thermal behavior and capacity. The influence of valve port parameters (such as opening, angle and discharge) exhibit the heat characteristics of the throttle valve on the pressure difference between front and back of the valve

The common structure forms of throttle valve are:
1) Needle throttle; 2) eccentric groove; 3) axial triangular groove; 4) Throttle circumferential gap type

The hydraulic radius of the throttle of the axial triangular groove is large due to its stability in the small discharges. For the convenience of study, only the throttle form of the axial single triangle groove is considered.
The hydraulic oil flows from the left end of the valve inlet to the lower right end of the outlet flow of throttle valve as shown in Figure 3. Due to the molecular collision of the oil it generates more heat upon increasing the ratio of collision to decrease its opening.

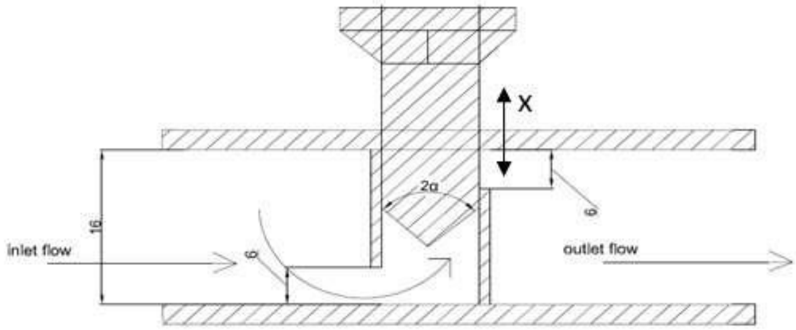

Fig.3 Throttle valve two-dimensional Geometric model

x is the opening value of the valve, and α is the angle perpendicular to the axis in the triangular groove as shown in figure.3. The opening variation highly influences the pressure difference when the valve opening of the throttle valve is large. The thermal element parameter adjustment in the thermal system has a certain reference function.

2. Analysis of simulation results

A throttle valve is used to generate the heat for the domestic hydraulic heating system which is used in different opening degrees for the maximum opening of the two-dimensional model is about to 10 mm as shown in figure.6. The calculated openings are 10 mm, 8 mm, 6 mm, 4 mm and 2mm for the proper analyses of the throttle valve. Matlab software is used to simulate the opening of throttle valve. The influence of the angle on the pressure difference can effectively prevent the fluid impurity from affecting the flow field. Some assumptions are made in order to analyze the valve characteristics.

1) The compressibility of the liquid is not considered;
2) It is assumed that the valve core is compatible with the valve sleeve and there is no radial clearance and no leakage.
3) The flow of the system almost does not change in a fixed working condition.

4) It is assumed that the fluid used is the Newtonian viscous fluid in which the dynamics viscosity does not change with change of the velocity deformation.
5) It is established that the flow is the stable in which the discharge of the fluid is same throughout the analysis which is applicable for the continuity equation principles.
6) There is a lot of pressure loss while fluid passing through the throttle valve, which exhibit that the flow is turbulent.
7) There is an abrupt change in pressure drop when the opening is very small about 2mm which is shown in figure.4.
8) The velocity changes is directly proportional to pressure drop in throttle valve as velocity of the fluid contain to its normal behavior when it passes through throttle valve while pressure drop increase which is shown in figure.4.
9) The relationship between fluid velocity and thermal effect is influence by the pressure drop in throttle valve which is shown in figure.5.

The oil parameters used in analysis are list below in table 1.

Table 1: hydraulic oil parameters

Parameter	Symbol	Value
Density	P	$870\ kg/m3$
Dynamic viscosity	µ	$.04kg/m^2$
Conduction coefficient	K	$0.132\ \frac{w}{mK}$
specific heat	C_p	$1.9\ \frac{kJ}{kgK}$

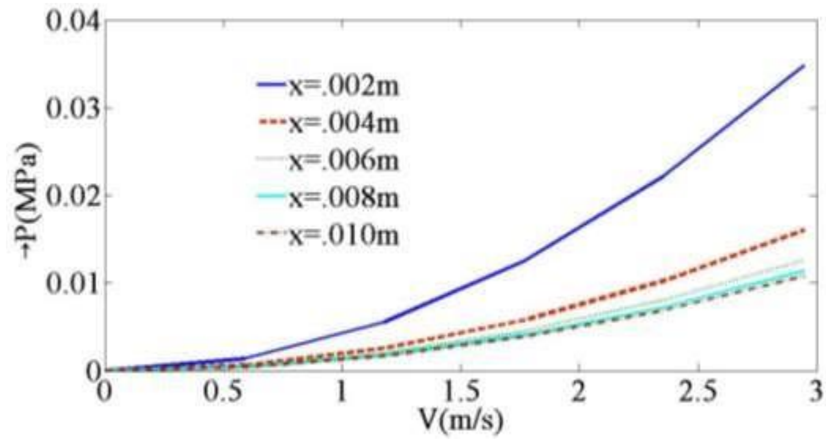

Figure.4 Throttle valve Pressure difference and velocity diagram at Different opening

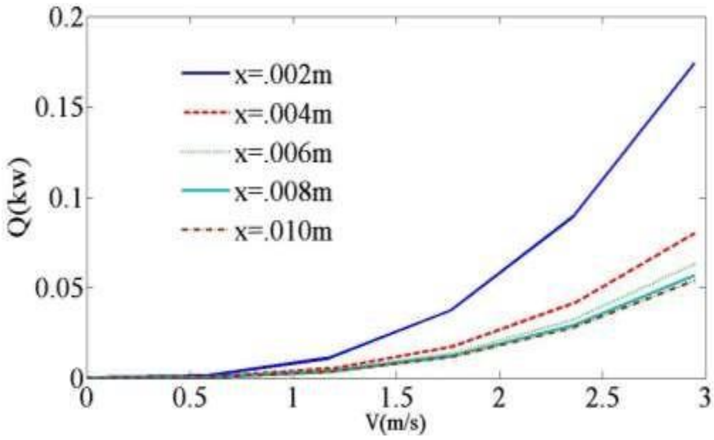

Fig .5 Throttle valve Thermal and velocity diagram under different openings

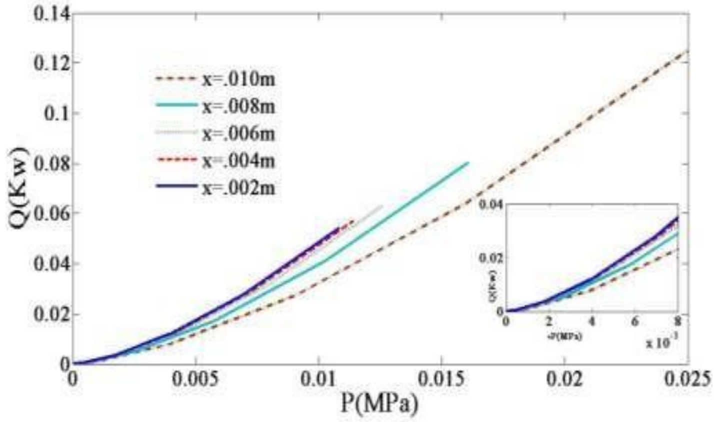

Fig. 6 Throttle valve thermal and Pressure drop diagram under different openings

It is observed that the change in angle and displacement of the throttle valve, the pressure difference between the two ends of the valve is also has the massive changes which can be verified by earlier figures. Although the throttle valve port is small in the opening but in case of small displacement and the small angle, there is a large amount of pressure drop can be achieved. In this case there is a phenomenon of rigidity in the throttle valve. The pressure difference between the two ends of the valve mouth is easily influenced by the external factors such as the flow pulsation of the pump, the particle of the impurity, the fluctuation of the load. It is explicit through the results by the Matlab to verify the characteristics of the throttle valve shown in figures that more heat can be generated through decreasing the considerable amount of the valve at a particular distance to a minimum value at constant discharge as mention in figure.6. It is also indicates that the heating effect of the system is influenced by the opening and angle of the valve opening create noise loudly.

Conclusion

This article is a study of the thermal characteristics of the throttle valve orifice of a domestic wind hydraulic heating system. It gives the certain significance in efficient utilization of wind energy in the commercial filed. For this purpose the Physical Model and simulation and mathematical model attempts the proper way of wind hydraulic heating system. The calculated results are the evidence for various kinds of comparisons in the characteristics analysis of needle throttle valve for the thermal enhanced purposes. The comparison of its different heat generating capacity under the condition of constant flow rate and Analysis of the pressure difference of the opening, angle and stiffness of the throttle valve that actually influence the heat causing effect. The simulation verification is consistent with the theoretical results. The thermal performance of the best appropriate opening is demonstrated in the simulation results. There are similar changes in velocity of the fluid in the presence of the same flow rate. The small change in the opening of the valve causes a significant change in the pressure difference at the both ends of the valve. The pressure difference at the both ends of the valve also presents a similar change within the change of the angle of needle valve which is basically consistent with the theoretical results. Furthermore the throttle valve can produce larger pressure difference in the case of small opening and small angle, this will lead generate more heating effects. Due to the pressure drop the velocity of the fluid enhances for proper thermal effect to generate more heat to drop in heat exchanger. The pressure difference between the both ends of the valve is easily affected by the flow pulsation of the pump and impurities presented in the oil particles and the influential external factors contains fluctuation and vibration effects in hydraulic pipe lines. The Simulation and analysis results on Throttle Valve indicate an excellent and perfect approach to a thermal hydraulic system by wind energy for a domestic and commercial resolution.

References

[1].Loganathan, B., et al., *Effect of sizing of a Savonius type vertical axis micro wind turbine.* Energy Procedia, 2017. 110: p. 555-560.

[2].Hamzehlouia, S. and A. Izadian. *State-space representation of a hydraulic wind power transfer*. in *Electro/Information Technology (EIT), 2012 IEEE International Conference on*. 2012. IEEE.

[3].Xinsheng, G., Z. Zhixin, and T. Guihua, *Experimental study on wind energy converting to heat by increasing fluid pressure and flow throttling.* Acta Energiae Solaris Sinica, 2004. 25: p. 157-161.

[4].Saleta, M.E., D. Tobia, and S. Gil, *Experimental study of Bernoulli's equation with losses.* American journal of physics, 2005. 73(7): p. 598-602.

[5].Khalid, M., et al., *On maximizing profit of wind-battery supported power station based on wind power and energy price forecasting.* Applied Energy, 2018. 211: p. 764-773.

[6].Maiti, S., R. Bandyopadhyay, and A. Chatterjee, *Vibrations of an Euler-Bernoulli beam with hysteretic damping arising from dispersed frictional microcracks.* Journal of Sound and Vibration, 2018. 412(Supplement C): p. 287-308.

[7].Zhu, H., et al., *CFD simulations of flow erosion and flow-induced deformation of needle valve: Effects of operation, structure and fluid parameters.* Nuclear Engineering and Design, 2014. 273: p. 396-411.

[8].Deldar, M., A. Izadian, and S. Anwar. *Modeling of a hydraulic wind power transfer system uitilizing a proportional valve*. in *Energy Conversion Congress and Exposition (ECCE), 2013 IEEE*. 2013. IEEE.

[9].Hou, C.-w., et al., *Parametric analysis on throttling components of multi-stage high pressure reducing valve.* Applied Thermal Engineering, 2018. 128: p. 1238-1248.
[10]. Jin, Z.-j., et al., *Numerical simulation and structure improvement of double throttling in a high parameter pressure reducing valve.* Journal of Zhejiang University SCIENCE A, 2013. 14(2): p. 137-146.
[11]. Cheng, W.-L., et al., *Theoretical analysis of a wind heating conversion and long distance transmission system.* Energy Conversion and Management, 2017. 137(Supplement C): p. 21-33.
[12]. Alia, M.A.K., T. Younes, and H. Sarhan, *Hydraulic Domestic Heating by Throttling*. Engineering, 2010. Vol.02No.06: p. 5.
[13]. Cengel, Y.A., et al., *Fundamentals of thermal-fluid sciences*. 2008: McGraw-Hill New York, NY.
[14]. White, F.M., *Fluid mechanics, WCB.* Ed McGraw-Hill Boston, 1999.