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Thermal Analysis of Sequence Hydraulic System

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Abstract- The Industrial Applications are used Hydraulic systems in widely. But heating the problem of has become and a crucial case to limit the technology advancement of hydraulic. High temperature, the operation of the hydraulic system will be at risk, causing serious failure and stuck. Through the energy conversion, inherent friction and fluid carriage losses. Thermal energy will be generated in the system, causing the temperature of the fluid to rise for keeping the system temperature in safe limits. This heat has to be dissipated by appropriate means. In this study, the aim is to assess the impact of flow rate, pressure, duty time and ambient temperature on the estimated oil temperature rise profile. The result showed increasing oil temperature rises in the hydraulic system with increasing flow rate, pressure, duty time and ambient temperature.

Keywords: *Parameters (ambient temperature, duty time, pressure and flow rate), a system of hydraulic sequence and temperature rise.*

1. Introduction

The system of hydraulic has a smooth transmission, compact structure, small size, overload protection, bearing capacity and other features, so it is usually utilized in the industrial field. When the hydraulic oil temperature increases, the leakage will increase in the hydraulic system, causing the effect of control stability and accuracy, therefore, become a fundamental cause for the limitation of hydraulic technology [1]. It is therefore essential to analyze the thermal system of the hydraulic system to control the oil temperature of the hydraulic system in the permissible range. Therefore, the thermal cause of the hydraulic system is difficult and complicated so that it will consume energy and time. The change in viscosity with temperature. The higher the viscosity index, the decrease the sensitivity of viscosity to temperature [2]. They observed that when the fluid temperature rises, the effective bulk agent of the liquid reduces, reducing the bulk factor directly to reduce the significant fluid hardness, and hydraulic motors are sensitive to temperature changes with time [3]. An analysis was performed to determine the effect of process variables on oil viscosity and studied the influence of time, pressure and temperature on the viscosity of various lubricant specimens [4]. The method of prediction was applied to a real hydraulic system. The oil flow dynamics were designed with a one-dimensional heat generation mechanism using ordinary differential equations [5]. The fundamental approaches of modelling thermal-hydraulic component briefly. A mathematical model of lumped factor set is advanced that are depending on the conservation of energy and mass [6]. The influence of temperature-oil and pressure changes on the efficiency of the hydraulic system at different temperature and pressure levels was studied by Hassan and Ibrahim [7]. The viscosity of the oil was found to rely mainly on the temperature and the influence of the strain on the viscosity that could be easily seen at low temperatures. The increasing temperature in the neutral circuit is quicker and more generous than that in the charging circuit, where the oil temperature at the tank approaches (59.1 ° C) for the neural circuits and (52.4 ° C) for the loading circuit at a pressure of 40 bar with the same period (240 min). The proportion was 11.33%. The pressure losses proportion in the neutral and loading circuit measurements with a 40 bar pressure at the same period of (240 min) are 10.2 percent and 11.65 percent, respectively, leading to further loading circuit losses. The efficiency of the machine depends primarily on the temperature and operating time. Lahari and Reddy [8], intended to minimize the excessive oil temperature by adjusting the construction, the tank material, supplying fins over it and increasing the performance of the power pack by minimizing heat losses, were examined and analyzed Understanding of the work was evaluated using the design expert program, and the error was just 0.01 per cent where the work was evaluated utilizing less than 0.05 percent indicates model terms are essential. The direct-driven hydraulic test rig without control valves was identified by Tatiana Minav el.at[9], who researched it from a thermal viewpoint. The relation between the outcome of the simulation and the test results validates the models advanced for the hydraulic system. The experimental tests suggest temperature increase throughout the lifting period, and it was treated throughout lowered. The energy analysis approach examined by Chao Wu et al.[10] is utilized to evaluate the heating of the constant-pressure device to assess the technical condition of the hydraulic parts, and the heat source is correctly discovered that has significant practical importance. The hydraulic system's heating value is related to the decrease in pressure and flows through the system. The hydraulic system heat source could be reliably discovered by calculating the applicable data and comparing it with the sample data. The starting pressure of a safety magnitude needs to be set higher than that of an outlet port pump for the constant-pressure system. However, a high-pressure overflow anomaly could occur, resulting in heating of the area. Hydraulic pipe track with a minimal diameter causes significant pressure loss, quickly contributes to system heating. Hence a fair selection of pipeline diameter is critical. The thermal device model was rational, and it was able to forecast the temperature increase of fluid temperature and research the thermal aspects of a hydraulic method, heat production and dissipation to approximate the temperature rise and steady-state temperature profile. Badrinarayanan et al.[11], studied the hydraulic system of land gear. A steady-state theoretical temperature of approx. After about one hour of activity, the temperature increase of the machine was inside limits (71 C0) following half an hour of experimental activity (62.51 ° C).

2. Heat Gain of Hydraulic system

Heat is obtained from external sources in case of a cold beginning environment of a hydraulic system, through different losses and from components.

2.1. Gained heat from the heating

In a cold start environment, some heating of fluid is provided to obtain certain temperatures. The heat gain from heating is:

$$P_W = V_T \, C \, \rho \, \frac{T_1 - T_2}{H} \tag{1}$$

Where

P_W- Heat flow in W

V_T- Volume of oil in a tank in Litter

C - Specific thermal capacity in kJ/kg K

ρ - Average of density in kg/ m^3

T_1, T_2 - Temperatures in K

H - Time of heating in h

Properties of oil hydraulic

ρ = 890 kg/m^3

c = 4.7 kJ /kg K

Due to the temperature of the low surroundings, you must maintain a fixed temperature for the system that loses heat.

$$Q_w = k \, A \, (T_1 - T_2) \tag{2}$$

Whereas

Q_w- Gained Heat of Required W

k - Coef. convection of heat transfer in kW/m^2K

A - Area of Heat dissipation in m2

T_1, T_2- Oil Temperatures and surroundings respectively in K

2.2. Gained Heat from Losses

The entire power losses of the hydraulic sequence system consist of several losses shown as follows:

$$P_{total} = P_{l.1} + P_{l.2} + P_{l.3} + P_{l.4} \tag{3}$$

Where

$P_{l.1}$- Losing of Power because of components' efficiencies.

$P_{l.2}$ - Losing of Power because internal leakages

$P_{l.3}$ – Losing of Power because throttling

$P_{l.4}$- Losing of Power because flow resistance

$$P_{l.1} = \frac{V\,p}{600}\left(\frac{1}{\eta} - 1\right) \qquad (4)$$

V = Total flow rate in Litter/min

p = pressure of operating in bar

η = Total efficiencies

$$P_{l.2} = \frac{V_l\ \Delta p}{600} \qquad (5)$$

V_l- Inner leakage in Litter/min

Δp- Pressure drop in bar

$$P_{l.3} = \sum \frac{V_t\,p_t}{600} \qquad (6)$$

V_t- Flow rate of a valve in Litter/min

p_t- Pressure drop at the valve in bar

$$P_{l.4} = \frac{V\ \sum \Delta p}{600} \qquad (7)$$

V- Total flow rate in Litter/min

$\sum \Delta p$- Total of all pressures in bar

3.2. Heat losing out of components

Heat losing occurs out of the hydraulic system components, the tank, pipe, and heat exchanger at a rate consist of the surface-area, fluid velocity and thickness of the wall.

3. Thermal balance and temperature profile

The oil-hydraulic temperature count on losses of power, the surface area of thermal radiating and installation place. Also, the most significant permitted oil temperature count on the kind of oil, the system required, and the duty cycle of the operation. Compare gained thermal to thermal loss, the consequent be the temperature recollected by the system through time. This thermal gathering intends to increase the oil temperature, which is assessed.

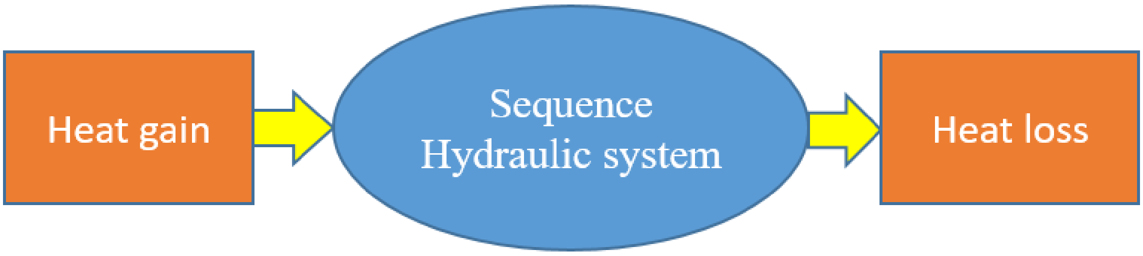

Figure 1. Thermal balance of Hydraulic system.

4. Thermal Balance Calculation

Assuming a Lumped of system analysis in heat transfer analysis. However, the foremost of checking the number of Biot validity is the proportion of the convection surface to the transmission.

4.1. Biot Number.

$Bi = \frac{h\,Lc}{K}$ .... (8)

$L_C = \frac{Volume}{Area}$ .... (9)

Whereas

Bi - Number of Biot

h - Coefficient of heat-transferring in W/m^2K

Lc - Length of Characteristic in m

K – Thermal-conductivity in W/m k

Total volume of oil=61.15 dm^3

Total area = 3.89 m^2

Therefore,

$Lc = \frac{Volume\ of\ oil}{Area}$ = (61.15 X 10^{-3}) / 3.89 = 0.0157 m

Biot number: $\mathbf{Bi} = \frac{\mathbf{h\,Lc}}{\mathbf{K}}$

Material Aluminum of Thermal conductivity in W/m.C

Bi = (10X 0.0157) / 204= 7.69607 X 10^{-4}

If the **(Bi << 0.1).** the system will become perfect and heat conduction and ignored the heat conduction as well as Temperature gradient, Heat balance formula:

Power Losses= energy absorbed+ Heat dissipated to surrounding by convection

5. Experimental work

Hydraulic preparation was carried out in the laboratory, and limited seat testing was performed using obtainable resources. The circuit remained the same as to the fundamental requirements, but the length of the pipe was limited owing to the restricted obtainability of pipes. The hydraulic pumps were driven by an electric motor that consumes 24 volts DC of a power source. The system run according to its functional requirements, and the liquid temperature rise in the tank was monitor. The laboratory setting, as demonstrated in **Figure 2** and **Table 2** specification device used in the experiment**.** The test was a performer at room temperature 30 ° C and the system has been worked for half an hour, and the temperature rise of the liquid was measure from the tank.

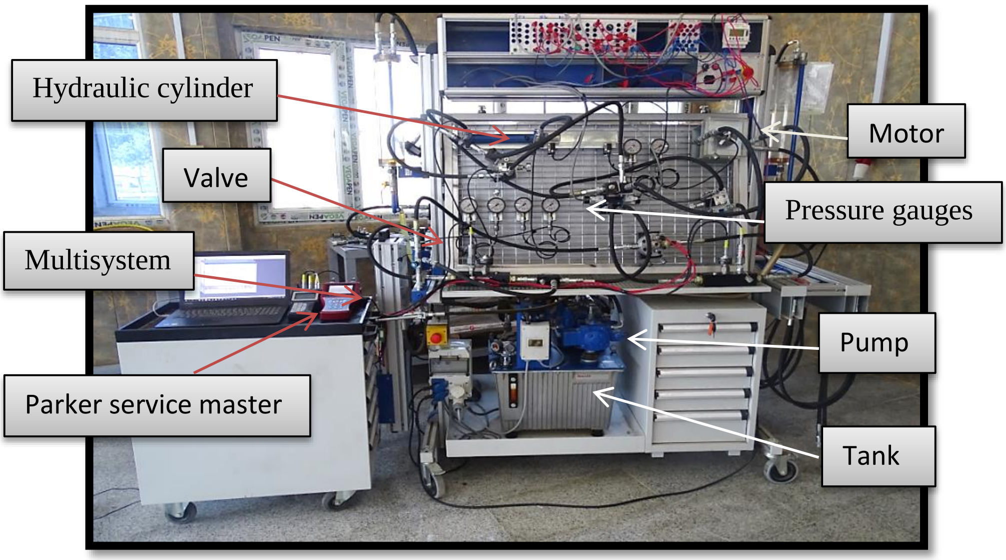

Figure 2. Laboratory testing system.

Table 2. Specification device used in the experiment.

No.	**Component**	**Volumes (m^3)**
1	pump	0.05
2	cylinder	0.1
3	Motor	0.07
4	Tubing	0.842
5	valves	0.0966
6	reservoir	60

6. Results & Discussion

Experimental work included the experimental estimation of the increase oil temperature in the sequential hydraulic system so that to reduce the period of the system exhaustion resulting from the rise of the oil temperature. The experimental work included the behaviour of temperature profile through different flow rate (Q= 3, 5, 7 l/min), and three variable pressure of the system (P= 40, 50, 60 bar), with change the time the operation of the hydraulic motor (t=2, 5, 10 seconds). The experimental work was carried out by taking three ambient temperature (T=20, 30, 40°C), and study their effects on the temperature rise of the hydraulic system.

6.1. The Effect of Flow Rate

Figure (3) shows the oil temperature inside the reservoir as a function of operation time and flow rate. It shows that the temperature increased to the steady value 49. 9 °C, when the flow rate increase at 7 l/min, while the value of the steady temperature was(42.3 and 34.9 °C) at flow rate 5 and 3 l/min, respectively. The percentages of increasing the temperature were (36%, 48%, 55%) at the flow rate (3, 5, and 7 l/min) respectively. The higher the flow rate the greater temperature due to the increased velocity of flow furthermore.

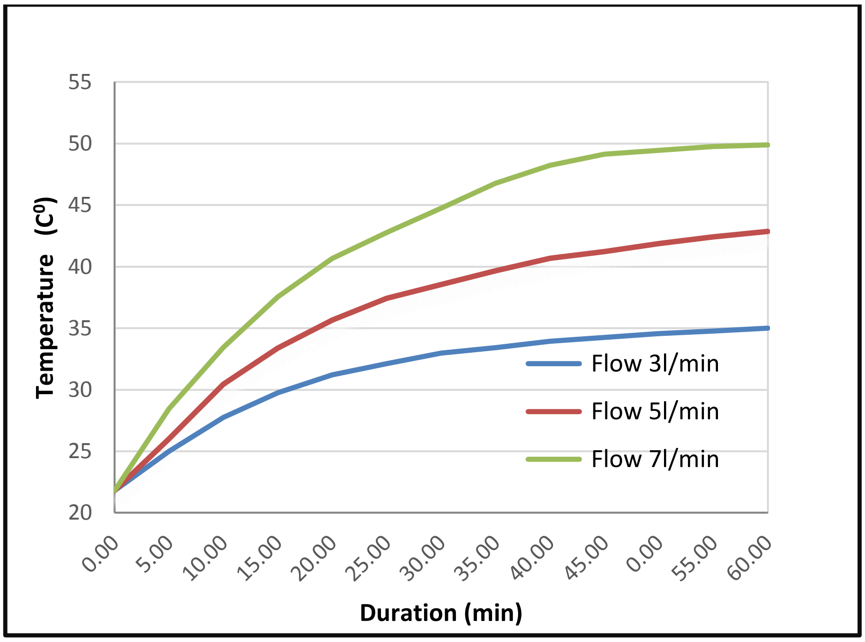

Figure 3: Correlation between the time and temperature profile with a different flow rate

6.2. The Effect of Setting Pressure

Figure (4) shows the gradually increased in temperature until it reached a steady value of 42.66 °C at a time one hour when the pressure is 60 bar. While at pressure (40, and 50 bar), the temperature reached a steady value (35.9, 39.33 °C) respectively. The percentages of increasing the temperature were (39%, 44%, 49%) at the pressures (40, 50, and 60 bar) respectively. Because of the increase of heat generation through components with an increase of pressure drop across components.

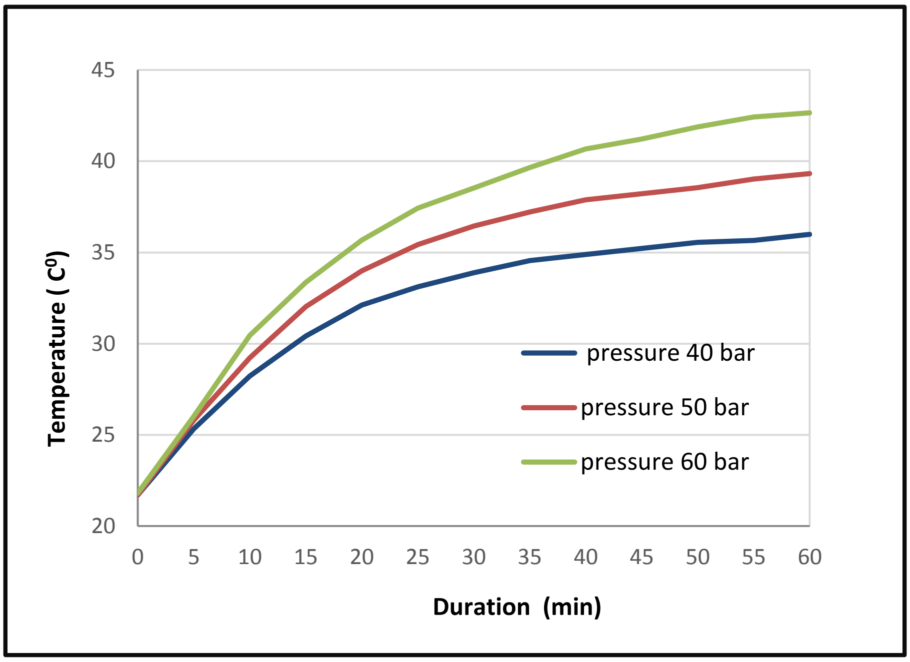

Figure 4: Correlation between time and temperature profile with different pressure

6.3. The Effect of Duty Time

Figure (5) shows all the temperatures inside the tank starting from 23 ºC and increased gradually to the greater values (35, 38, and 40.9 ºC) at periods (2, 5, and10 second) respectably. The percentages of the increasing of the temperature were (33%, 38%, and 43%) at duty times (2, 5, and 10 seconds) respectively. Affects in two sides first increase temperature because of increase of heat generation by hydraulic motor second decrease temperature because of increase heat dissipation by tank

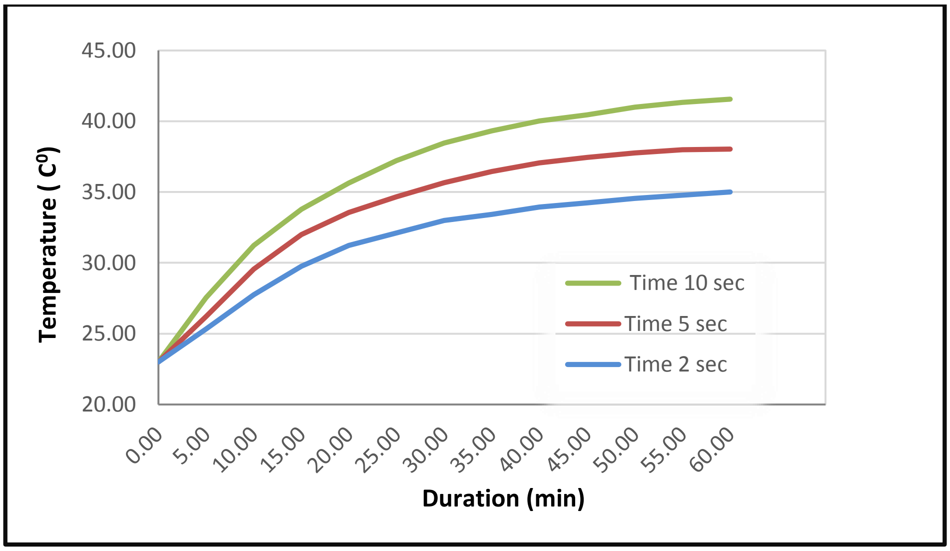

Figure 5: Correlation between temperature time and profile

6.4. The Effect of ambient temperature

Figure 6 shows the comparison between the ambient temperatures were the oil enters the reservoir and the operation time. The temperature the oil enter reservoir starting from 20 ^oC and increases gradually to the steady value 40.9 ^oC, when the ambient temperature 20 ^oC, and when the ambient temperature 30, 40 ^oC the temperature of the oil enters the reservoir (30, 40 ^oC) reached to the steady temperature values of 52, 61.8 ^oC, respectively. This increments of the temperature because of the heat generation were the additional increase in temperatures at the inlet 20, 30 and 40 ^oC is 10 ^oC While, the increase in temperature at the outlet 40.9, 51.7, and 62 also is 10 ^oC, this because the heat dissipation is equal at the inlet and outlet for each case. The percentage of the increasing temperature was (51%, 41%, 34%) at the ambient temperatures (20, 30, and 40 ^oC) respectively. It is noticed that the difference between ambient temperature and the enduring value of temperature for three tests are approximately equated (22 ^oC) because the effect of viscosity is relatively small.

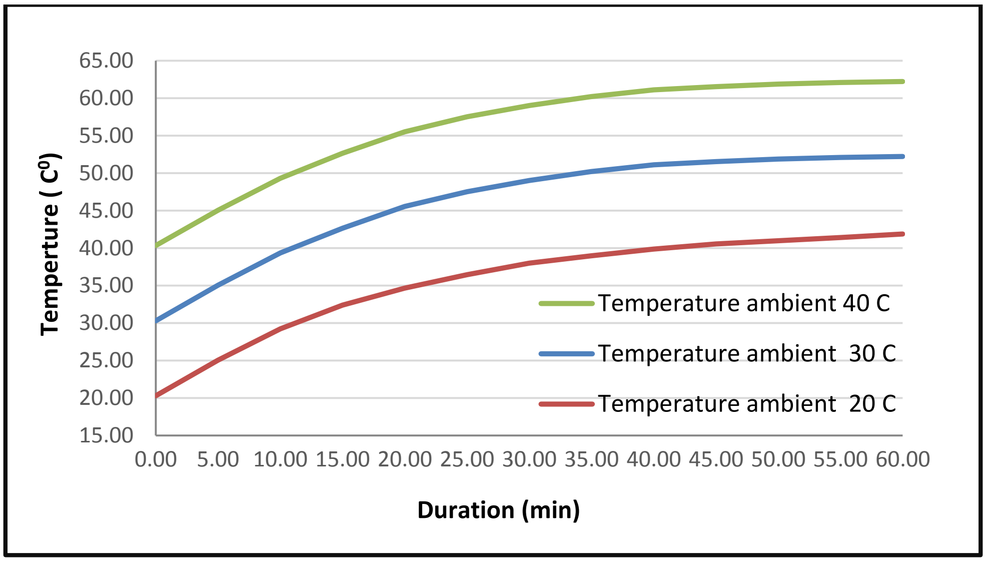

Figure 6: Correlation between time and temperature profile with a different ambient temperature

7. Conclusion

This study to estimated oil temperature and affect the pressure, flow rates, duty time and ambient temperature on the hydraulic systems. The hydraulic system during the investigation has been estimated for different heat factors, and temperature degrees was determined:

1- The percentages of increasing the temperature were (36%, 48%, 55%) at the flow rate (3,5and 7 l/min)respectively.
2- Increasing the heat generation through components leads to increasing of pressure across components.
3- The percentages of the increasing of the temperature were (33%, 38%, and 43%) at duty times (2, 5, and 10 seconds) respectively.

4- The percentage of the increasing temperature was (51%, 41%, 34%) at the ambient temperatures (20, 30, and 40 ^oC) respectively.

The previous results know the parameters that affect the hydraulic system shows the parameters that follow to get a better result.

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