ANALYSIS OF POWER REQUIRED IN TUBE FURNACE USING DAQ MASTER PROGRAM

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Abstract

Analysis of power required in tube furnace using DAQ master program. The tube furnace was used to control the temperature and testing data of heating element in tube furnace with resistance of 9, 16, and 23 ohm. The efficiency of the furnace was tested by operating it with electrical voltage of 22, 27, 31, 37, 47, 80 and 100 volt to target temperature 1000 ^{0}C. Based on testing performed, first tube furnace by resistance 9 ohm couldn't reached temperature of 1000 ^{0}C due to low electrical power, while second tube furnace by resistance 16 ohm, temperature could be reached 1000^{0}C with electric power of 338.4 watt during 5732 second and 499.5 watt during 5775 second, then for third tube furnace by resistance 23 ohm, temperature 1000^{0}C could be reached with electric power of 333 watt during 5735 second. Result testing by resistance 23 ohm has more efficient electric power at temperature 1000^{0}C. By calculating the temperature effect to resistance, resistance of heating element by 9 ohm obtained result was in range of resistance from 9.01 – 9.11 ohm, then for resistance 16 ohm was in range of resistance from 16.02–16.24 ohm, and resistance 23 ohm was in range of resistance from 23,03 – 23,34 ohm.

Keywords: electrical power, tube furnace, resistance, temperature controller, DAQ master program

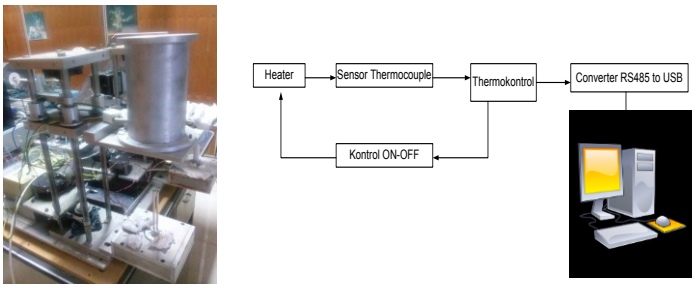
INTRODUCTION

The process of heating or melting material to forming materials or analyze characteristic material by heat treatment a metal (example rolling, forging) or change it properties are used by furnace [1,2]. Heat energy obtained from electrical energy which was generated in heating element to chamber room. Furnace sample is being a heating until setting or target temperature. Furnace temperature varies between 30 ^{0}C to 1700 C. Temperature sensor was used to determine area of furnace heating. Temperature sensor consist in several types according to the temperature range such as J type sensor, K , R , and S [3].

Research was a preliminary design of Differential Thermal Analysis (DTA) design. DTA used for analyzing characteristics material exothermic or endothermic while heating process based on thermal scanning between sample material and reference material, such as temperature changes in the atom structure, chemical reaction and decomposition [12]. So, preliminary study of design development for the DTA with the tube furnace is considered by the electrical power efficiently. This research will be carried out analysis of the electrical power requirements for tube furnace design with different resistance, then testing tube furnace until temperature 1000 ^{0}C. Voltage variation was give under 100 volt, based on availability of voltage transformer tap in laboratory. Furnace system added with control system computer in real time. So, amount of current and temperature can be read by using DAQ master program. Data from testing performed can be calculated power and electrical energy from tube furnace.

EXPERIMENTAL PROCEDURE

Differential Thermal Analysis (DTA) used tube furnace for heating area. This equipment was developed by Research Center for Physics LIPI.



a) b)

Figure 1. a) Differential Thermal Analysis [12]
b) Block Diagram temperature control

Tube Furnace DTA was designed to determine required electrical power. Electrical power on tube furnace was calculated by the formula 1,

$$P = V.I.Cos\ \varphi \qquad 1$$

Where, P is for power (Watt), V is for voltage (Volt), and Cos φ is for power factor. Electrical energy calculated in unit of Joules was calculated based on following formula 2:

$$W = P.t \qquad 2$$

Where, W is for energy (joule), P is for power (W) and t is for time (s). Calculation a conductor or element in heating process was certainly give an effect to resistance of heating element. Calculation resistance change defined by the following equation,

$$R_T = R_{20}\,[1 + \alpha\,(T - 20^0C)] \qquad 3$$

Where, R_T (ohm) is for resistance at temperature T, R_{20} (ohm) is for resistance at temperature of 20 ^{0}C (ohm), and α is for temperature coefficient (/K), and T is for temperature (^{0}C) [1,5]. Figure 1b) show a block diagram of the basic concept temperature control system. DAQ Master program have feature parameters graphic form, setting time and read all the parameters in thermo control and ampere meter.
Figure 2a show tube furnace material made from ceramic. Tube will be wrapped around heating element for first tube furnace by distance of 4 cm, the second tube furnace by distance of 8 cm, and a third tube furnace by distance of 12 cm. The distance along the heating element was wound with a coil spacing of 5 mm (Figure 2a).

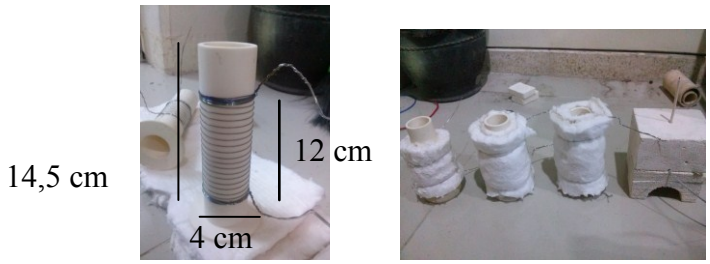


Figure 2. a) Chamber room furnace. b). Ceramic Board Tube Furnace

Resistance values from measurement of each tube furnace are 9 ohm, 16 ohm, and 23 ohm. After coil heating element has been wound in tube furnace, then covered insulator or ceramic board which has capacity heating power up to 1200 ^{0}C as show in figure 2b. Heating element was tested with a voltage below 100 volt in 1000 ^{0}C. In experiment used two step-down transformers 220 volt to 100 volt, then a second transformer 220 volt to 50 volt, 60 volt, 70 volt, 80 volt and 100 volt. So from measurement, get value of voltage 22 volt, 27 volt, 31 volt, 37 volt, 47 volt, 80 volt, 100 volt and voltage and current could be measurement [4,5].

Shown in figure 3. there are several main component temperature control (a) thermocontrol for reading and adjust temperature of an object. Thermocontrol work based thermocouple sensor that detecting heating object and then process received data from the thermocouple and give a current output of 4-20 mA to turn on and off contactor or Solid State Relay (SSR).

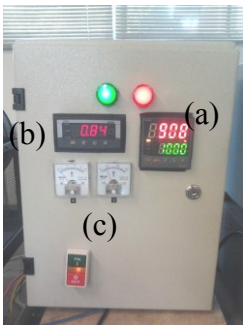


Figure 3. Control system temperature (a). thermocontrol (b). digital amperemeter (c) analog amperemeter and voltmeter

RESULT AND DISCUSSION

Testing on resistance heating element 9 ohm

Data obtained by operating temperature control system until 1000 ^{0}C in real time (figure 6). Testing tube furnace with voltage variation by 22 volt, 27 volt, 31 volt, 37 volt, 47 volt, 80 volt and 100 volt.

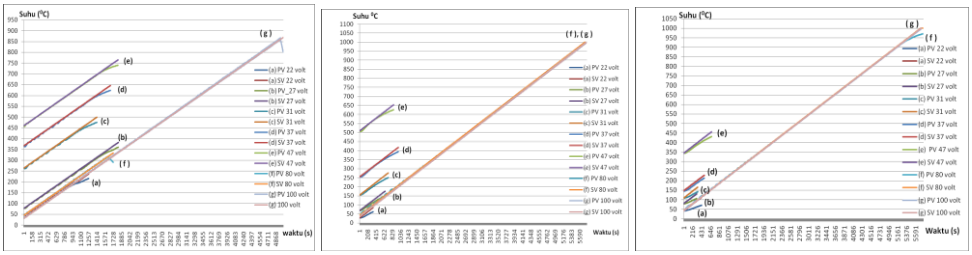


Figure 4. Testing Data heating element 9 ohm, 16 Ohm and 23Ohm

Figure 4 show result testing between times to temperature. Process temperature was defined as Processing Value (PV) and target temperature was Setting Value (SV). The parameters obtained from test performed was process temperature (PV), the target temperature (SV), secondary voltage on heating element tube furnace (V_2) and electric current heating element (I_2). When secondary transformer was

positioned at 50 volt, voltage measured was 22 volt, temperature process began at room temperature 36 C, but when process temperature was 216 ^{0}C and target temperature was 236 C, difference temperature was to large around 20 ^{0}C, so, heating process was stopped, because electric power to the tube furnace was low. Similarly with transformer tap voltage, temperature tube furnace was under 1000 ^{0}C. [table 1].

Table 1. Testing result tube furnace heating element 9 ohm

Voltage V_2 (V)	Current I_2 (A)	Power P_2 (W)	Energy W_2 (Joule)	Losses Trafo (W)	Efficiency Trafo (%)
22	2,07	40,99	51.150,53	2,57	94,09
27	2,57	62,45	114.035,53	0,91	98,57
31	3,02	84,26	118.803,78	0,88	98,96
37	3,53	117,55	196.541,93	5,21	95,76
47	4,1	173,43	319.284,63	18,63	90,30
80	8,92	642,24	8.991,36	28,98	95,68
100	10,8	972,00	470.448,00	25,92	97,40

Power generated in the tube furnace varies between 40.99 watt up to 972 watt. Power calculation on heating element in the result table 1 above can be show in the following calculation,

$$P_2 = V_2 . I_2 . Cos\ \varphi, \quad P_2 = 22.\ 2{,}07.\ 0{,}9 \text{ and } P_2 = 40{,}99\ watt$$

Based on data in Table 2, electrical energy was obtained,

$$W = P.t\ ,\ W = 40{,}99\ .1248\ ,\ W = 51.150{,}53 \text{ Joule}$$

Based on review result in table 2, resistance 9 ohm have not been able to reach temperatures until 1000 ^{0}C, highest temperature can be obtained at 860 C with secondary transformer voltage of 100 volt. Because power of heating element was low, heating process became slowly and when heating time was extended, difference was being higher between process temperature and temperature setting, when tube furnace give voltage of 80 volt and 100 volt, electric current flowing on heating element was 8.9 ampere and 10.8 ampere only able to reach a temperature of 860 ^{0}C and element was broken, because current flowing at heating element was high, not on capacity maximum of heating element.

Table 2. Comparison of voltage variation, time, and temperature

Voltage (V_2)	Heating Time (s)	Time reached temperature (s)	*Processing Value* (PV) (^{0}C)	*Setting Value* (SV) (^{0}C)
22	1248	1260	216	236
27	1826	1837	361	383
31	1410	1421	476	500
37	1672	1683	623	646
47	1841	1832	740	765
80	14	1622	316	314
100	484	4974	860	859

Table 2 are shown result of comparison between voltage variation, time, and temperature reached in resistance 9 ohm. Heating time was defined by time when the electric current flowing in heating element, in This case the output voltage control system for the heating element was ON state. Then the temperature was reached when total time of the heating process from the beginning until the temperature was reached includes process control ON and OFF overall interval time.

Data obtained by operating temperature control system until 1000 ^{0}C in real time. Voltage measured by 22V, temperature reached by 62^{0}C and setting temperature reached by 84 ^{0}C, heating process was stopped, because target temperature could not reached, because power electric was low [Fig 4]. Different when heating element was give voltage of 80V and 100V are reached until 1000 ^{0}C. Electric power supplied to heating element tube furnace sufficiently, so temperature can be reached.

Table 3. Testing result tube furnace resistance 16 ohm

Voltage V_2 (V)	Current I_2 (A)	Power P_2 (W)	Energy W_2 (Joule)	Losses Trafo (W)	Efficiency Trafo (%)
22	1,2	23,76	7.959,60	1,98	92,31
27	1,58	38,39	24.341,80	5,17	88,14
31	1,72	47,99	34.455,38	1,51	96,95
37	2,31	76,92	75.076,85	4,26	94,76
47	2,61	110,40	94.615,37	4,44	96,14
80	4,7	338,40	563.774,40	12,06	96,56
100	5,55	499,50	647.352,00	11,34	97,78

Based on the review in table 3 electric power heating element with resistance 16 ohm acquired 23.76 watt until 499.50 watt. Temperature was reached when voltage of 80 volt, power generated by 338,4 watt and 100 vol, power generated was 499.5 watt.

Tabel 4. Comparison of voltage variation, time, and temperature

Voltage (V_2)	Heating Time (s)	Time reached temperature (s)	*Processing Value* (PV) (^{0}C)	*Setting Value* (SV) (^{0}C)
22	335	359	62	84
27	634	656	150	175
31	718	734	251	276
37	976	989	393	418
47	857	867	626	653
80	1666	5372	1000	1000
100	1296	5775	1000	1000

By 22V to 47V, maximum temperature was reached 626^{0}C and 1000^{0}C temperature by given a voltage of 80V and 100V.

Testing on resistance heating element 23 ohm

Data obtained by operating temperature control system until 1000 ^{0}C in real time. Figure 4 show that voltage to heating element by 22 volt, 27 volt, 31 volt, 37 volt and 47 volt still not reached target temperature in 1000 C, different with heating element was gave voltage of 80 volt, temperature process was reached at 972^{0}C and the temperature of the process in 1000^{0}C can be reached when heating element was given 100V.

Tabel 5. Testing result tube furnace resistance 23 ohm

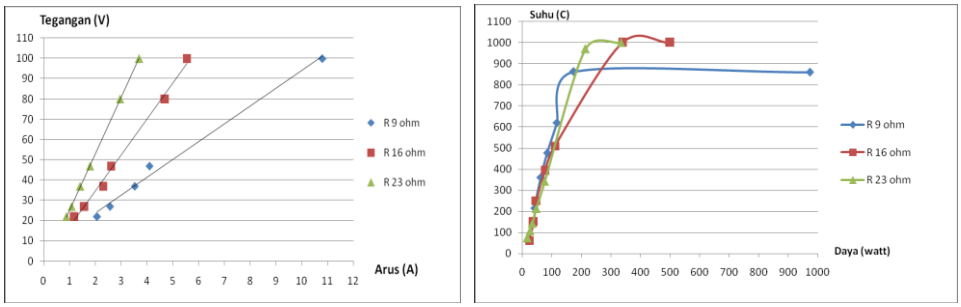
Voltage V_2 (V)	Current I_2 (A)	Power P_2 (W)	Energy W_2 (Joule)	Losses Trafo (W)	Efficiency Trafo (%)
22	0,88	17,42	7.387,78	2,38	88,00
27	1,08	26,24	8.161,88	1,48	94,68
31	1,24	34,60	11.312,89	3,02	91,96
37	1,42	47,29	23.548,43	4,19	91,85
47	1,8	76,14	50.480,82	3,06	96,14
80	2,96	213,12	645.753,60	8,64	96,10
100	3,7	333,00	684.315,00	9,54	97,21

Based on the review in table 5 power the heating element with 23 ohm resistance acquired 17.42 watt until 333 watt. temperature 1000 ^{0}C was reached by 100 volt and generated power was 333 watt.

Tabel 6. Comparison of voltage variation, time, and temperature

Voltage (V_2)	Heating Time (s)	Time reached temperature (s)	*Processing Value* (PV) (^{0}C)	*Setting Value* (SV) (^{0}C)
22	424	448	73	113
27	311	320	106	132
31	327	348	143	165
37	498	515	213	230
47	663	681	432	456
80	3030	5786	970	1000
100	2055	5735	1000	1000

Table 6 is shown the result of the comparison between voltage variation, time, and temperature reached in resistance 23 ohm. In the measurement voltage 22 volts to 80 volts, maximum temperature was reached 970^{0}C and 1000 ^{0}C temperature of the process could be reached when heating element was given voltage of 100 volt.



a) b)

Figure 5. a) Current-Voltage and b) Power - Temperature Comparison

Figure 5 shows characteristic of heating element when give in same voltage source. A voltage measurement on heating element was 22V, 27V and 100V. The maximum electric current flowing in heating element with resistance 9 ohm was 10.8 A and minimum of 2.07 A. The maximum electric current in resistance 16 ohm was 5.55 A and minimum of 1, 2 A. Then for R 23 ohm has max electric current of 3.7 A and min of 0.88 A.

Figure 5 shows comparison between electrical power to temperature of 1000 ^{0}C. Graphic show maximum power obtained on temperature of 1000 ^{0}C amounted 338.4 watt and 499.5 watt from resistance 16 ohm. While maximum power at resistance 23 ohm was 333 watt. Based on result of the calculation of electrical power to each heating element, obtained electrical power efficiently in third tube furnace with the different element was tube furnace with resistance 23 ohm and electric power of 333 watt at voltage of 100 volt with heating area inside tube furnace larger, because design length of winding resistance 23 ohm with coil length by 12 cm.

Calculation of the effect of temperature against resistance

To determine resistance at a specific temperature calculation using the following formulation,

$$R_T = R_{20}\,[1 + \alpha\,(T - 20^0C)]$$

Calculation of heating element resistance at T=150 ^{0}C, $R_T = 9{,}01\ \Omega$. T=250 ^{0}C R change to temperature was not too significant, which produces 9.01 ohm from 9 ohm. Calculation also doing for temperatures up to 1000 ^{0}C. To get a deviation from measurement result and calculation is 0,88%. Figure 6 shows a comparison between temperature and resistance in heating element. Maximum temperature could reached 860 ^{0}C in resistance 9 ohm. Calculation result obtained resistance value between 9 to 9.11 ohm. Calculation of resistance based on test result obtained 9,09 ohm until 9.62 ohm. Deviation between data calculation and measurement was 0.87% to 5.6%.

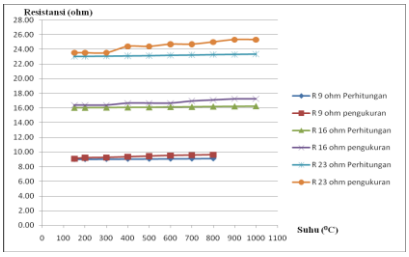


Figure 6. Temperature- resistance change Comparison

On resistance 16 ohm, maximum temperature could reached 1000 ^{0}C. Value of resistance range 16.02 to 16.24 ohm. Calculation of resistance based on test result obtained 16.39 ohm resistance until 17.24 ohm. Deviation of comparison between data calculation and measurement was 2.31% to 6.2%. On R 23 ohm, maximum temperature could reached 1000 ^{0}C. Value of resistance range 23.03 to 23.34 ohm, calculation of

resistance based on test result obtained 23.53 ohm resistance until 25.32 ohm. Deviation of comparison between data calculation and measurement was 2.16% to 8.48%. Electric current flow in circuit was getting smaller due to resistance value was increase. Applied voltage was constant at 100 volt.

Refer to result of calculation and measurement of each resistance heating element, there was a difference between calculation and measurement. It was caused by several factors such as the reading of the measurement from instrument error, correction factor on the appliance and voltage fluctuation in the circuit.

CONCLUSION

From the research, it can be concluded that:

1. Based on test performed in first tube furnace with R 9 ohm, temperature (T) could not reached 1000 ^{0}C, beacause electrical power was low, while tube furnace with R 16 ohm, T could reached 1000 ^{0}C with electric power of 338.4W for 5372 sec and 499.5W for 5775 sec, and R 23 ohm, T of 1000 ^{0}C could reached with electric power of 333 W for 5735 sec. Power consumption more efficiently with R 23 ohm by T of 1000 ^{0}C.
2. Calculation effect of temperature on R showed that tube furnace with heating element resistance 9 ohm obtained result change in resistance between range of 9.01 to 9.11 ohm, 16 ohm while R are in range of R change 16.02 - 16.24 ohm, 23 ohm and for R=23 ohm resistance change by 23.03 to 23.34 ohm.

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