Development and engineering of heat press machine tools

Cite as: AIP Conference Proceedings **2659**, 130002 (2022); https://doi.org/10.1063/5.0121899
Published Online: 29 November 2022

Mukti Hamjah Harahap, Winsyahputra Ritonga, Budiman Nasution, et al.

Development and Engineering of Heat Press Machine Tools

Mukti Hamjah Harahap[a)], Winsyahputra Ritonga, Budiman Nasution, Arman DS Tumanggor, Putra Stevano Frima Yudha

Department of Physic, Faculty of Mathematic and Natural Science, Universitas Negeri Medan, Indonesia, Jl. Willem Iskandar, Pasar V, Medan, Sumatera Utara – Indonesia

[a)] *Corresponding author: mhfis08@gmail.com*

Abstract. Engineering technology for utilizing electrical energy into heat energy or other energy needed by the industrial world is one of the national research master plans (RIRN). This is also in line with the research strategic plan of the State University of Medan which encourages the implementation of research in the field of energy. This research raises the topic of electrical energy utilization and optimization for Hydraulic Heat Press machines. Where the Hydraulic Heat Press machine often experiences Heat Loss due to an inefficient open heating system modeling. This press machine is designed to optimize the heat generated by the Heater against the sample and is designed to produce a Heat Press in a machine with a closed system. So that the process of forming or suppressing the sample becomes better and optimal. Press machines are capable of producing pressures of up to 120 Bar, the heating system of the Press machines is able to heat the sample up to a temperature of 500C and is able to control the constant heat increase, and the Press machine is also able to cool the sample with an efficient cooling system and does not damage the sample due to heat shock. The design of the Hydraulic Heat Press machine starts from the design of the Hydraulic Heat Press, designing the heating element, and designing the cooling system, designing the heating and cooling system control system in the Hydraulic Heat Press Machine Design. Heating control system to regulate the temperature rise of the Heat Press Machine. Before being manufactured, the Heat Press Machine system will be tested simultaneously in order to obtain a Press Machine that is safe, easy to operate, durable and inexpensive. From the results of this study, it is targeted that the output is a calibrated prototype of the heating system and also the pressure system until it is ready for manufacturing.

INTRODUCTION

In the current era of modernization, the use of press machines is considered less than optimal due to inefficient modeling. The working principle of the machine uses heat and pressure, in contrast to machines on the market that use the principle of injection and pressure. Some of the press machines that have been produced and are on the market today still have several weaknesses, including heating elements embedded in the heating chamber which tend not to last long against high temperatures. Another weakness that is no less important is the system for controlling and reading the indoor temperature which is often inaccurate and does not match the actual heat (2).

Limitations and shortcomings in the current press machine can be overcome through several actions such as designing a temperature control system based on a thermal sensor with a level of heat resistance that exceeds the working temperature of the heating system. The indicator of damage to the heating element also needs to be inserted in the press machine which is equipped with a monitoring system for reporting output in real time. The heat press machine must be properly designed with the number of heating elements, the thickness of the ceramic insulator and the outer steel layer to get a high working efficiency from the press machine [1].

METHODS

The type of data obtained from this research is quantitative and qualitative data. Quantitative data in the form of exact number from the measurement result of standardized tools such as temperature rise measurement, electric voltage measurement, control system data. The data is in several numeric extension format that need to be processed

The 8th Annual International Seminar On Trends In Science And Science Education (AISTSSE) 2021
AIP Conf. Proc. 2659, 130002-1–130002-8; https://doi.org/10.1063/5.0121899
Published by AIP Publishing. 978-0-7354-4256-6/$30.00

and converted into graph and table. Furthermore, an analysis is carried out according to the phenomenon that occurs by comparing it to several results from previous reputable journal article. While the qualitative data include the result of the analysis of the efficiency of the heating system which can be described by qualitative analysis.

Heating Press Temperature Test

The manufacture of heat press requires specific data, including determining the rate of heat transfer in the heating plate. In determining the rate of heat transfer in heating plate, we must know the thermal conductivity (U) of each material.

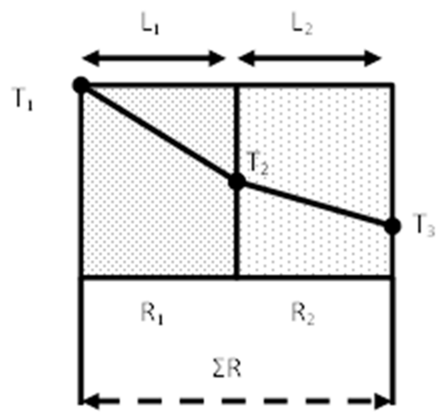

FIGURE 1. Heating Plate Lining Material Structure

Based on Figure 1, it must be known in advance the amount of conductivity of each material used as a lining material for heat plate in heat press machine.

TABLE 1. Specification of heat plate lining material of heat press machine.

Material	Thermal Conductivity (W/mK)	Layer Thickness (m)
Refractory	1,51	0,06
Iron	80	0,01

Using the heat transfer rate equation below, we can calculate the heat released through each lining material for the heat plate of heat press, namely:

$$Q = \frac{\Delta T}{R} = \frac{(T_1 - T_2)}{R} \quad (1)$$

Where : Q : Heat from the surface of material, W.
R : Thermal resistance of the material surface area, K/W.
T_1 : Refractory temperature K.
T_2 : Iron Plate temperature K.

Based on Equation (1) thermal resistance material can be known through,

$$R_n = \frac{L_n}{K_n A} \quad (2)$$

Where : R_n : Thermal resistance of the material surface area, K/W.
L_n : Material thickness, m.
K_n : Thermal Conductivity of material, W/mK.
A : surface area of the material, m^2.

The test was carried out by operating the heating system until the surface heat plate temperature reached the maximum temperature (450 ºC) and held for 2 hours, observation is made by recording the time, temperature rise inside plate and the outer layer, voltage, and operating current of heat press heating, as presented in Table 2.

TABLE 2. Data on direct observation of time, temperature rise, voltage, and current on heating press testing

n	T_1 (°C)	T_3 (°C)	t_n (s)	V (Volt)	I (Ampere)
0	…	…	…	…	…
	⋮	⋮	⋮	⋮	⋮
n	500	…	…	…	…

Where : n : Heat from the surface of material, W.
T_1 : Refractory temperature °C.
T_2 : Iron Plate temperature °C.
t_n : time, s.
V : Heat press machine heating input voltage, Volt.
I : Heat press machine input current, Ampere.

After the observation data is obtained, the researcher can analyze the heat-loss and temperature in each layer of the heat plate surface of heat press machine so that we can analyze the total heat-loss as energy loss, and researcher can analyze the power in the heat press heater during testing as Energy input, to be able to analyze the energy efficiency of the heat press machine, as the data can be presented in Table 3.

TABLE 3. Heat press machine temperature test result data.

N	T_1 (°C)	T_2 (°C)	T_3 (°C)	Q_{loss}	t_n (s)	V (Volt)	I (Ampere)	P (Watt)	η (%)
0	…	…	…	…	…	…	…	…	…
	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮
N	…	…	…	…	…	…	…	…	…

Where : n : index of observational data.
T_1 : Refractory temperature °C.
T_2 : Iron Plate temperature °C.
T_3 : Iron Plate Outer Surface temperature °C.
Q_{loss} : Total heat released in heat press machine, watt.
t_n : time, s.
V : Heat press machine heating input voltage ,Volt.
I : Heat press machine heating input current, Ampere.
P : Heat press machine heating power input, Watt.

RESULT AND DISCUSSION

In this test, the heat press machine is just opreate the heating system. Set the temperature to reach a maximum temperature of heat press machine heating system up to 450 ºC . Observational data as shown in Table 4.

TABLE 4. Temperature rising test result

N	T_1 (°C)	T_3 (°C)	t_n (s)	V (Volt)	I (Ampere)
0	33,00	33,00	0,00	227,00	10,00
1	40,00	40,00	123,00	217,00	11,50
2	50,00	50,00	199,00	216,00	9,90
3	60,00	60,00	256,00	216,00	8,80
4	70,00	70,00	311,00	216,00	9,70
5	80,00	80,00	362,00	216,00	9,20
6	90,00	90,00	400,00	216,00	9,50
7	100,00	100,00	448,00	216,00	9,60

N	T_1 (°C)	T_3 (°C)	t_n (s)	V (Volt)	I (Ampere)
8	110,00	110,00	498,00	216,00	6,80
9	120,00	120,00	549,00	216,00	11,40
10	130,00	130,00	591,00	216,00	11,20
11	140,00	140,00	640,00	218,00	9,40
12	150,00	150,00	696,00	216,00	9,10
13	160,00	160,00	752,00	216,00	10,61
14	170,00	170,00	808,00	216,00	10,40
15	180,00	180,00	868,00	216,00	9,90
16	190,00	190,00	930,00	216,00	11,00
17	200,00	200,00	997,00	217,00	9,50
18	210,00	210,00	1071,00	215,00	8,90
19	220,00	220,00	1149,00	215,00	10,50
20	230,00	230,00	1231,00	217,00	8,80
21	240,00	240,00	1317,00	216,00	9,30
22	250,00	250,00	1410,00	219,00	11,40
23	260,00	260,00	1507,00	216,00	9,80
24	270,00	270,00	1606,00	217,00	9,50
25	280,00	280,00	1708,00	217,00	12,20
26	290,00	290,00	1820,00	218,00	11,30
27	300,00	300,00	1932,00	215,00	9,20
28	310,00	307,00	2047,00	215,00	9,40
29	320,00	317,00	2180,00	215,00	9,00
30	330,00	326,00	2330,00	214,00	11,10
31	340,00	336,00	2476,00	215,00	11,50
32	350,00	345,00	2612,00	216,00	11,10
33	360,00	354,00	2763,00	216,00	10,00
34	370,00	364,00	2929,00	215,00	11,70
35	380,00	373,00	3091,00	217,00	11,70
36	390,00	383,00	3261,00	215,00	12,10
37	400,00	393,00	3418,00	216,00	9,70
38	410,00	403,00	3590,00	217,00	8,70
41	420,00	412,00	3727,00	216,00	9,20
40	430,00	421,00	3883,00	216,00	9,00
41	440,00	431,00	4058,00	216,00	9,10
42	450,00	441,00	4236,00	215,00	9,90

Based on the data above, we can see that during the heating process, the temperature measurements at the refractory temperature (T1) and the surface temperature of the heating plate are equal from the beginning until it reaches temperature of 300ºC, when the refractory temperature reaches temperature of 310ºC to 450ºC there are differences in temperature measurements at the surface temperature of the heating plate reaching ±3ºC. This shows that the decrease in thermal energy (thermal loss) that occurs during the test process increases the temperature on the heat press machine quite small.

To calculate the rate of heat transfer generated from the heating element, and also to calculate the temperature distribution in each layer in an heating plate of heat press machine with a capacity of 2200 Watt. Some of the data obtained for the thermal conductivity of each heating plate lining material of heat press machine are shown in table 1, the data describes the structure, thermal conductivity, and thickness of the coating material used in heat press machine.

To find out the total heat transfer rate in the heat press machine through the data on Table 4, Figure 1 explain the layer structure of the heating plate lining material of heat press machine and use the heat transfer rate equation at Equation 1 so that the total heat energy is reduced (thermal loss) becomes:

$$Q = \frac{(T_1 - T_3)}{R_{total}} \tag{3}$$

Using temperature measurement data on each heating plate lining material of heat press machine at Table 4., then converted into Kelvin, obtained reduced heat energy (thermal loss) when the measurement temperature in the refractory reaches 450ºC (maximum). Using the result of the calculation of the reduced heat energy (thermal loss) above, we can calculate the temperature distribution for each electric furnace lining material using Equation 3, then we get The temperature distribution in the Iron Plate temperature (T_2) is 446,01ºC.

So to calculate the thermal efficiency of the heat press machine. Using heat press machine heating voltage and current measurement data on Table 4. to calculate the electrical power required by the heating element, and using the result of the calculation of the reduced heat energy (thermal loss) above, then use the energy conversion efficiency equation in the following system,

$$\eta = \frac{(E - E_{Loss})}{E} \times 100\% \tag{4}$$

Where : η : Energy efficiency, %.
E : Total energy required.
E_{loss} : Energy obtained from a heated material.

Using the electric energy equation,

$$P = I \times V \tag{5}$$

Where : P : Electrical energy, Watt.
I : current strength, Ampere.
V : voltage, volt.

Based on the measurement data of the voltage and current measured on the heating element in Table 4 and use Equation 5, and by assuming the electrical energy required by the heating element as the input energy, and the reduced heat energy (thermal loss) as the energy obtained from a heated material. Use Equation 4 then we get, the thermal efficiency of the heat press machine (at the measurement temperature of 450ºC) is 98,59%, which means that 2150 Watt of electrical energy needed by heat press machine heating element to heat the the heating plate is only 0.25. % of wasted energy loss.

Using the calculation result above, the reduced heat energy (thermal loss), the temperature distribution of each heating plate lining material of heat press machine, the electrical energy of the heating element, and also the energy efficiency of the heat press machine can be obtained from each temperature measurement data displayed on Table 4, so that we can present it in Table 5.

TABLE 5. Calculation result of the temperature distribution, and thermal loss of the heat press machine test

N	T_1 (°C)	T_2 (°C)	T_3 (°C)	Q_{loss}	t_n (s)	V (Volt)	I (Ampere)	P (Watt)	η (%)
0	33,00	33,00	33,00	0,00	0,00	227,00	10,00	2270,00	100,00%
1	40,00	40,00	40,00	0,00	123,00	217,00	11,50	2495,50	100,00%
2	50,00	50,00	50,00	0,00	199,00	216,00	9,90	2138,40	100,00%
3	60,00	60,00	60,00	0,00	256,00	216,00	8,80	1900,80	100,00%
4	70,00	70,00	70,00	0,00	311,00	216,00	9,70	2095,20	100,00%
5	80,00	80,00	80,00	0,00	362,00	216,00	9,20	1987,20	100,00%
6	90,00	90,00	90,00	0,00	400,00	216,00	9,50	2052,00	100,00%
7	100,00	100,00	100,00	0,00	448,00	216,00	9,60	2073,60	100,00%
8	110,00	110,00	110,00	0,00	498,00	216,00	6,80	1468,80	100,00%
9	120,00	120,00	120,00	0,00	549,00	216,00	11,40	2462,40	100,00%
10	130,00	130,00	130,00	0,00	591,00	216,00	11,20	2419,20	100,00%
11	140,00	140,00	140,00	0,00	640,00	218,00	9,40	2049,20	100,00%
12	150,00	150,00	150,00	0,00	696,00	216,00	9,10	1965,60	100,00%

N	T_1 (°C)	T_2 (°C)	T_3 (°C)	Q_{loss}	t_n (s)	V (Volt)	I (Ampere)	P (Watt)	η (%)
13	160,00	160,00	160,00	0,00	752,00	216,00	10,61	2291,76	100,00%
14	170,00	170,00	170,00	0,00	808,00	216,00	10,40	2246,40	100,00%
15	180,00	180,00	180,00	0,00	868,00	216,00	9,90	2138,40	100,00%
16	190,00	190,00	190,00	0,00	930,00	216,00	11,00	2376,00	100,00%
17	200,00	200,00	200,00	0,00	997,00	217,00	9,50	2061,50	100,00%
18	210,00	210,00	210,00	0,00	1071,00	215,00	8,90	1913,50	100,00%
19	220,00	220,00	220,00	0,00	1149,00	215,00	10,50	2257,50	100,00%
20	230,00	230,00	230,00	0,00	1231,00	217,00	8,80	1909,60	100,00%
21	240,00	240,00	240,00	0,00	1317,00	216,00	9,30	2008,80	100,00%
22	250,00	250,00	250,00	0,00	1410,00	219,00	11,40	2496,60	100,00%
23	260,00	260,00	260,00	0,00	1507,00	216,00	9,80	2116,80	100,00%
24	270,00	270,00	270,00	0,00	1606,00	217,00	9,50	2061,50	100,00%
25	280,00	280,00	280,00	0,00	1708,00	217,00	12,20	2647,40	100,00%
26	290,00	290,00	290,00	0,00	1820,00	218,00	11,30	2463,40	100,00%
27	300,00	300,00	300,00	0,00	1932,00	215,00	9,20	1978,00	100,00%
28	310,00	307,01	307,00	22,58	2047,00	215,00	9,40	2021,00	98,88%
29	320,00	317,01	317,00	22,58	2180,00	215,00	9,00	1935,00	98,83%
30	330,00	326,01	326,00	30,11	2330,00	214,00	11,10	2375,40	98,73%
31	340,00	336,01	336,00	30,11	2476,00	215,00	11,50	2472,50	98,78%
32	350,00	345,01	345,00	37,64	2612,00	216,00	11,10	2397,60	98,43%
33	360,00	354,02	354,00	45,17	2763,00	216,00	10,00	2160,00	97,91%
34	370,00	364,02	364,00	45,17	2929,00	215,00	11,70	2515,50	98,20%
35	380,00	373,02	373,00	52,69	3091,00	217,00	11,70	2538,90	97,92%
36	390,00	383,02	383,00	52,69	3261,00	215,00	12,10	2601,50	97,97%
37	400,00	393,02	393,00	52,69	3418,00	216,00	9,70	2095,20	97,48%
38	410,00	403,02	403,00	52,69	3590,00	217,00	8,70	1887,90	97,21%
41	420,00	412,02	412,00	60,22	3727,00	216,00	9,20	1987,20	96,97%
40	430,00	421,03	421,00	67,75	3883,00	216,00	9,00	1944,00	96,51%
41	440,00	431,03	431,00	67,75	4058,00	216,00	9,10	1965,60	96,55%
42	450,00	441,03	441,00	67,75	4236,00	215,00	9,90	2128,50	96,82%

Based on data on Table 5. we can find out the characteristic of the temperature distribution of each lining material with respect to time, and the reduced heat energy (thermal loss) in the heat press machine.

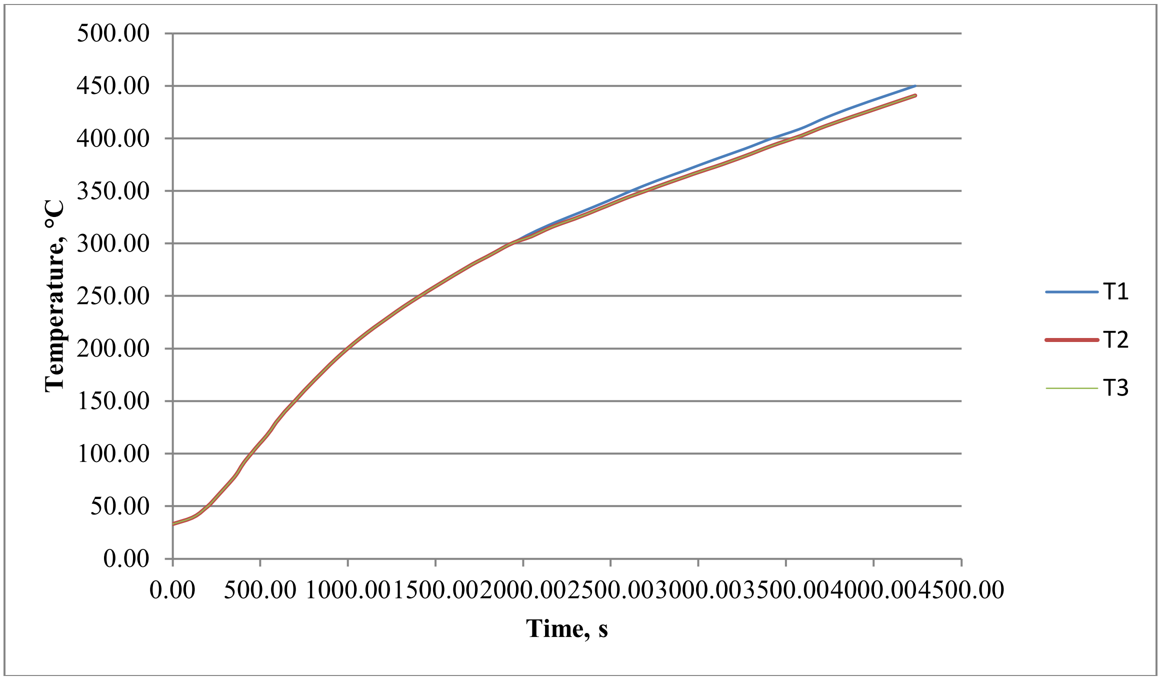

FIGURE 2. Temperature distribution of each lining material in the heat plate of heat press machine.

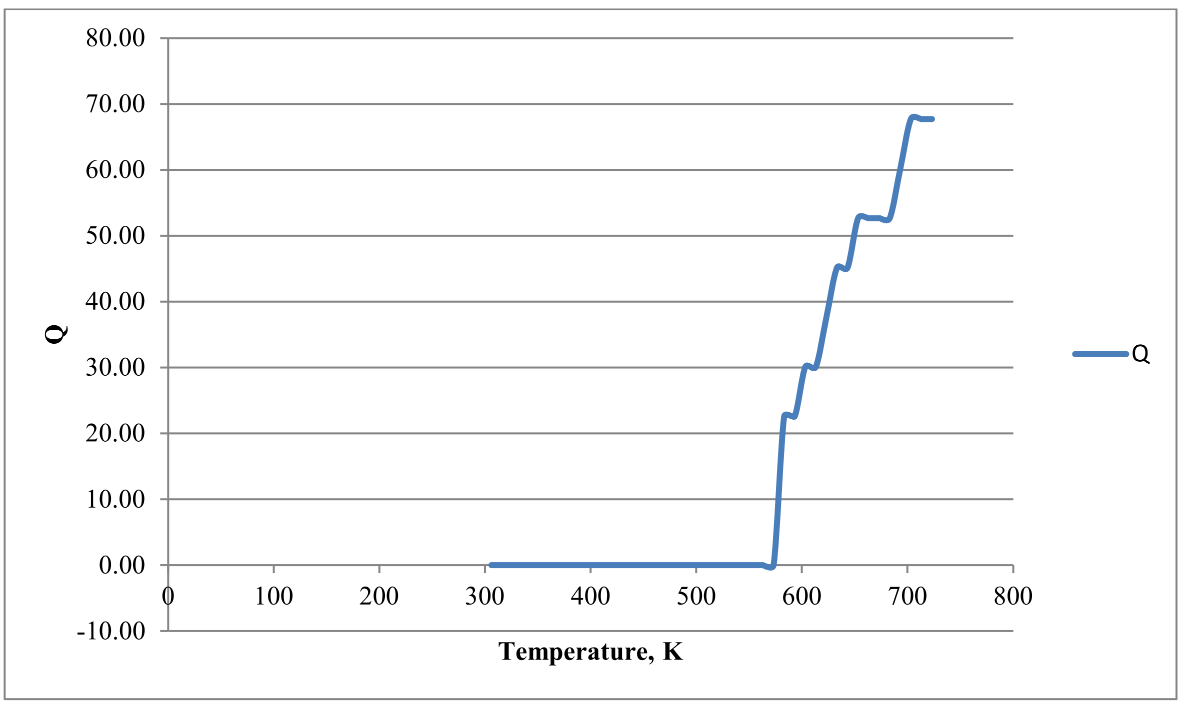

FIGURE 3. Thermal loss of the heat press machine against the measured temperature in the refractory.

CONCLUSION

Heating system of heating press machine has been successfully manufactured with a heating capability of up to 450ºC and possible to heat with a relatively low average power (±2200 Watt) than any heating heat press machine available in the market. The heating plate lining material used has been known to be very efficient based on the wasted heat transfer rate from the electric furnace combustion chamber at the maximum temperature (67.75 W).

REFERENCES

1. W. Ritonga, Putra, M.H. Harahap, J. Rajagukguk, F.Y.P. Stevano and M.A.R. Sembiring, Advances in Mechanics**9(3)**, pp. 750–780 (2021).
2. W. Ritonga et al, J. Phys.: Conf. Ser.**18(19)** (2021)
3. R. Hanifi, Marno, Kardiman, E. Widiantom, Journal of Infrastructure & Sciene Engineering**2(1)**, pp. 38-44 (2019).
4. T. Okazaki, Renewable Energy**151**, pp. 563-574 (2020).
5. N.K. Yusuf, M.A. Lajis, A. Ahmad, Materials**10(902)**, pp. 1-18 (2017).