

Design and Manufacture Electrolysis Equipment to Produce Magnesium Oxide Material

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Abstract - The use of Magnesium in the automotive field is diverse, it is necessary to source raw materials. One of the raw materials for magnesium can be obtain from nature which can be done by electrolysis and thermal reduction processes. Electrolysis is a chemical reaction process of decomposition by electric current in electrolytes with the help of electrodes. The electrolysis process to obtain magnesium requires a minimum temperature of around 725°C. This article discusses the design and manufacture of electrolysis devices with fuel using coke and wood charcoal. The methodology carried out includes design in the form of soft drawings, determination of tool dimensions, furnace design, air supply line design, temperature control device placement, argon gas line placement, coal fuel placement, and material selection. The manufacturing stage of electrolysis equipment includes the manufacture of furnaces consisting of the manufacture of the outer frame of steel plates, the installation of refractory stone insulation, the placement of air supply lines, the installation of blowers, the placement of argon gas lines, the placement of graphite electrodes. Placement of power supply in the form of an adapter that can be adjusted the voltage. The results of MgCl₂ electrolysis equipment have dimensions of a diameter of 325 mm and a height of 500 mm. The insulation thickness of the refractory stone is 120 mm. The size of the crucible diameter is 125 mm, and the height of the crucible is 160 mm. The time to reach a furnace temperature of 725°C is achieved within 20 minutes with a mixture of coal and wood charcoal fuel.

Keywords: Designing, manufacture, curcible, insulation, refractory stone, graphite, Magnesium chloride.

I. INTRODUCTION

The rapid development of technology in the field of materials is shown by the variety of magnesium materials and their alloys in the engineering industry (Hirsch and Al-Samman 2013). Magnesium can be applied in many fields. Magnesium material commonly used in automotive

components such as transmission cases, engine blocks, and in the field of health, magnesium is used as a biodegradable material (Ibrahim et al. 2017). The function of magnesium in the automotive industry is as an alloying element in aluminum, die casting, steel desulphurization, and other applications in the chemical industry (Wulandari et al. 2008).

The production of magnesium material can be carried out by several methods. These methods include the dow process and electrolysis process (Wulandari et al. 2008). The process can be done by dissolving Magnesium Chloride salt (MgCl₂) in the electrolysis process. In this process, an electric current is applied which passed through an electrolyte solution to produce a chemical reaction. In the process of electrolysis, two electrodes are used which contact the solution in this case the Magnesium Chloride salt (MgCl₂). The electrodes in this process used graphite material (Handaja, Susanto, and Hermawan 2020) The process of liquefaction of Magnesium chloride salt is carried out at a temperature of 725 degrees Celsius.

In the provision of the electrolysis equipment process, it is necessary to provide several considerations and components. These considerations include design aspects, manufacturing, selection of material, and assembly (Martínez-Rivero et al. 2019). Design aspects should be determining furnace dimensions, material type, operational temperature, operating costs, operation, maintenance, and pollution to the environment (Mubarak and Akhyar 2013). The furnace design must be capable to withstand temperatures of 725°C. A design of electrolysis equipment must be provided furnace which is capable to locate crucible and solid fuel.

The design process decided the dimensions of the furnace and the types of material which will be melted. The inner dimension of the furnace is diameter of 240 mm and the outer diameter of 480 mm. The height is 300 mm. The amount of melted material determines the heating energy of the furnace. (An et al. 2012). The furnace is a coated vessel that used a refractory material. This material withstands high-temperature operation until 1200°C (Haruna, Sankar, and Mohammed

2022). The furnace should be in a good condition and well operated.

The heating energy of burning furnaces can be derived from solid fuels, natural gas, and electricity. Currently, the heating furnaces for the electrolysis process were selected by using coke as a source of energy. The type fuel types used a wood charcoal and coal. Coal has a calorific value of 8300 kcal / kg while charcoal value of 200 kcal/kg (Bono, Wahyono, and S. 2017). The demand for oxygen for the burning process was supplied by the compressed air. The working temperature of the heating furnace is 725°C the supply of coal in the heating process was done to obtain a fast heating time.

The source of heat energy in the furnace must be well protected and not escape to the surrounding. The effort protection of heating escape to the surrounding is the selection of material insulation system. Selection of an insulation system in the combustion chamber using refractory stones. Refractory stone is used as a heat barrier that is good enough so that it is not affected by the surrounding environment. Fireproof stone with dimensions of length 23 cm x width 11 cm x height 6 cm can withstand temperatures up to 1200°C.

The achievement of working temperatures in furnaces up to 725°C with coal and charcoal fuel is reinforced by the presence of compressed air. Compressed air is as an oxygen supply for the fuel ignition process (Güden and Karakaya 1994). The supply of compressed air used a blower with a size of 2 inches. The compressed air flows through the piping system into the hole of the combustion chamber in the furnace. The other design of the furnace consists of crucible selection, combustion chamber, insulation, fuel determination, and blower selection.

The electrolysis crucible used is tubular with a diameter of 125 mm and a height of 165 mm. The material crucible is built up of graphite. The reason for crucible graphite is the material did not react with the surrounding and also magnesium material. In the center of the furnace is the electrolysis crucible. This crucible is in direct contact with the burning fuel. The crucible will be filled with magnesium chloride. Magnesium chloride is used as an electrolyte material in the electrolysis process. This electrolysis for the production of magnesium material used the molten salt of magnesium chloride for the production process (Demirci and Karakaya 2012). The melting of salt magnesium chloride is 714°C (Kennedy and Harris 2012), while magnesium has a melting point of 651°C and a boiling point of 1120°C (Kipouros G.J. and Sadoway D.R. 1987).

The process of electrolysis using magnesium chloride will release the chlorine gas. The chlorine (Cl_2) must be protected during the process. The protection of chlorine gas flowed through water glass. The flowing of chlorine gas into the water was done to convert gas chlorine into calcium hypochlorite ($\text{Ca}(\text{ClO})_2$). The material of calcium hypochlorite is safe for surrounding. The resulting chloride gas is flowed out through the drain hole assisted with argon gas to assist in the removal of chlorine gas. Argon gas is an inert gas that does not react with magnesium metal. Argon gas is channeled into the electrolysis dish through a hose and into the electrolysis dish.

On the lid of the electrolysis crucible, there are several holes for electrodes, gas supply, and temperature gauge. For supply, the electric current used is obtained through an adapter that produces direct current. The adapter used has a voltage of 12 volts and can be increased for voltage. The use of electric current is expected to occur a reaction at the electrode so that magnesium can carry out the electrolysis process.

The current process is an electrolysis process that uses inert electrode material. The inert materials include graphite, platinum, and gold (Jung, Yang, and Ahn 2011). The selection of electrodes is based on price, easily obtained, and availability. The decision of electrode material is graphite material due to cheaper (Shih, Su, and Huang 2015). The other selection of graphite materials is based on the reaction of the material to be electrolysed. Graphite electrodes are used because they do not react with magnesium and can still conduct electric current at high temperatures. Electrodes dimension in the electrolysis process has a diameter of 8 mm and 300 mm long.

In the electrolysis process, MgCl_2 electrolysis is an anhydrous process of liquid magnesium. The liquid moves towards the electrolyte and separates from chloride gas and magnesium (Güden, 1994).

This research aims to design and make an electrolysis device capable of working at a temperature of 725°C to perform magnesium chloride electrolysis.

II. MATERIAL AND METHODOLOGY

This article discusses the design and manufacture of MgCl_2 material electrolysis equipment. The stages carried out include Design, Material selection, and Equipment manufacturing.

The design stage carried out is the creation of equipment layouts. The design layout consists of furnace drawings, air duct laying, argon gas line laying, electrode laying, blower

laying, power supply laying, and control box laying. The layout is shown in Figure 1.

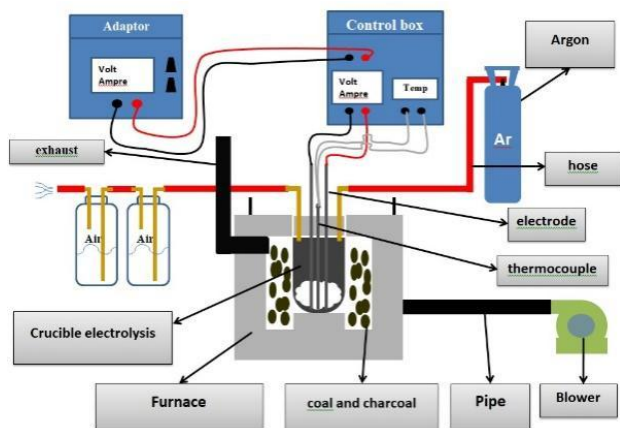


Figure 1: Layout of MgCl₂ electrolysis equipment

2.1 Tools and Materials

The tools used in this study are:

a) Heating Furnace

Is a heat insulation device made of refractory stone that is used as a heat generator through fuel. Furnace dimensions described in the furnace design (2.2).

b) Blower

Blower is a device used as an additional oxygen supply for the fuel combustion process. The bower used is 2 inches.



Figure 2: Blower

c) Temperature Gauge

The temperature is a device used as a sensor on an electrolysis dish to find out the temperature to be measured. The temperature measuring device uses a type K thermocouple with an adapter attached to an electrolysis dish and monitored in the control box.



Figure 3: Thermocouple

d) Hose

The hose is a device that connects a stream of argon gas into an electrolysis dish. The hose used uses a diameter of 8 mm.



Figure 4: Hose

e) Power Supply

Power supply is a power source used for the electrolysis process. Power supply uses a 12 Volt DC adapter connected to a power up to regulate the voltage of 6 volts to 30 volts.



Figure 5: Adapter and power up DC

f) Crucible

The Crucible is a reservoir for electrolyte fluids used in the electrolysis process. The saucer material uses graphite with a diameter of 125 mm x height of 165 mm.



Figure 6: Crucible electrolysis

g) Electrodes

The electrode is a conductor of electric voltage generated from power supply. The basic electrode material uses graphite with a diameter of 8 mm and a length of 300 mm.



Figure 7: Graphite Electrodes

h) Argon

It is the inert gas. The inert gas was supplied in crucible chamber during the electrolysis process to prevent electrolyte from being contaminated with oxygen. Argon gas is an inert gas that does not react with Mg and Cl. So it is expected to minimize oxygen gas in the electrolyte during the electrolysis process.



Figure 8: Argon

i) Timer

It is a tool that used to measure the time needed during the testing process. The timer used a stopwatch.

j) Scales

It is a tool which used to weigh the load on the $MgCl_2$ material. The scale is carried out to weigh by using digital scales.



Figure 9: Digital Scales

The materials used in this study were coal, wood charcoal, refractory cement, and $MgCl_2$.

k) Coal

Coal is a fuel used for the heating process in heating furnaces.



Figure 10: Coal

l) Wood Charcoal

Wood charcoal is the fuel used for the heating process in the heating furnace.



Figure 11: Wood Charcoal

m) Refractory Stone

This material is as an insulating material. The material was arranged to comply with furnace chamber in the electrolysis equipment. The insulating material can withstand temperatures up to 1000 °C.



Figure 12: Refractory Stone

n) Refractory Cement

Refractory cement is a refractory stone adhesive material used to stick refractory stone during the furnace manufacturing process.



Figure 13: Refractory Cement

o) Magnesium Chloride (MgCl₂)

This material is as an electrolyte material that will be used in the electrolysis process.



Figure 14: MgCl₂

2.2 Design a Furnace

Furnace design includes steps:

a) Make drawings of heating furnace construction designs. Design the heating furnace according to the size of the crucible and the fuel used. The design results are shown in figure 15.

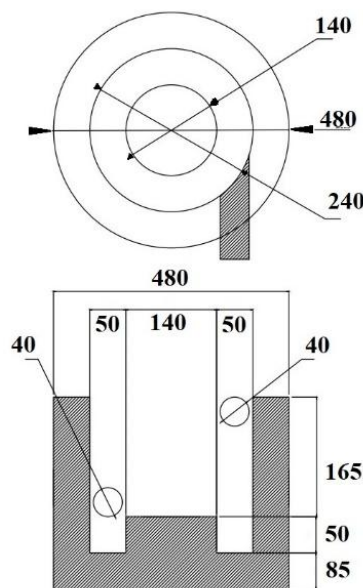


Figure 15: Heating Furnace Design

b) Determine the tools and materials used for heating furnace fabrication and furnace testing. The use of refractory stone as insulation with dimensions of 23 cm long, 11 cm wide, and 6.5 cm high. For refractory cement using neoset Am-308. Refractory stone can withstand heat up to 1200°C and for refractory cement up to 1500°C.

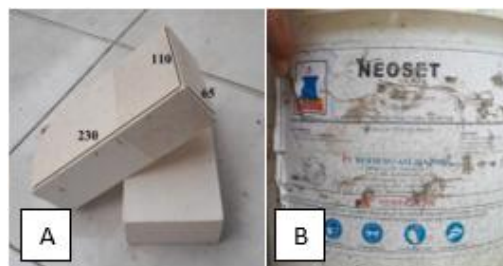


Figure 16: (A) Refractory Stone, (B) Mortar

c) Heating Furnace Fabrication

2.3 Furnace Testing

Testing required preparation and working procedures of the test. The testing stages that will be carried out in the framework of data collection up to data analysis are as follows:

- Heating Furnace Fabrication.
- Weighing the fuel used.
- Electrolysis crucible input.
- Fuel is fed into the combustion chamber of the heating furnace with varying weight. The amount of variation is:

Specimen	Coal	Wood Charcoal
	Weight (grams)	
BB1	1000	30
BB2	1000	60
BB3	1000	100

- The process of igniting fuel with the help of touch gas which is ignited through the input hole in compressed air.
- Turning on the blower and measuring time and temperature process.
- After the temperature reaches 725⁰C the blower is turned off and lifts the electrolysis crucible.

2.4 Electrolysis Preparation

The electrolysis testing process is used heating furnaces that have been prepared. The electrolysis testing steps are as follows:

- Fabrication of electrolysis crucible cap
- Weighing the weight of electrolyte material. The electrolyte used is MgCl₂ weighing 100 grams
- Electrolyte is inserted into the crucible
- Close the saucer and drain argon gas
- Turn on the thermometer and power supply
- Put it in the heating furnace
- Turn on the heating furnace. The ignition process is the same as furnace testing (2.3)
- Once the temperature reaches 725⁰C, set the temperature for 30 minutes
- Remove the electrolysis dish, let it sit until room temperature with voltage conditions and argon gas is still running
- Remove electrolysis results
- Put it in the prepared container
- Electrolysis result testing with XRF

2.5 Data Analysis

Data analysis performed to determine:

- Temperature of the furnace system
- Warm-up time
- Electrolysis process

2.6 Estimated fuel requirements (Istana, 2016)

Heat transfer can be calculated through the amount of heat needed in the melting process. The thermal efficiency in the furnace can be calculated through the following equation:

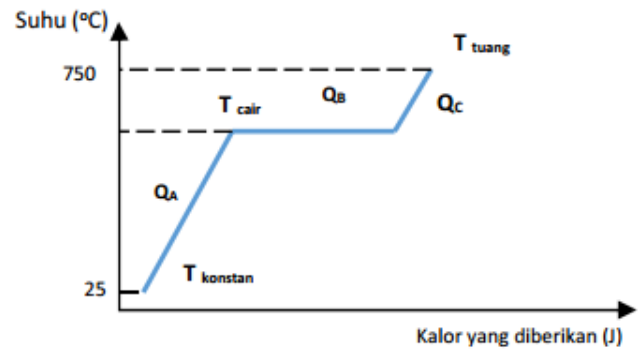


Figure 17: Heat Transfer Rate

a. Heat to Dilute MgCl₂

The amount of heat (Q) to be transferred into the koi can be calculated as follows :

$$Q_1 = Q_a + Q_b + Q_c + Q_d$$

$$Q_1 = M_{MgCl} \times C_{p1} \times (T_{liquid} - T_{pour}) + M_{Mgcl} \times C_{p1} + (T_{pour} - T_{liquid})$$

(Istana and Lukman 2016)

b. Capacity heat MgCl₂

$$C_{pMgCl} = 88,141 + 0,002 \times 10^{-3} \times T + 59,212 \times 10^5 \times T^{-2}$$

(Peng, 2016)

c. Heat Absorbed by The Crucible

$$Q_c = M_t \times C_{p2} \times \Delta T$$

(Adi, Raharjo, and Surojo 2014)

d. Heat Absorbed by Furnace

$$Q_t = M_t \times C_{p2} \times \Delta T$$

e. The Amount of Heat in the Total Amount

$$Q_{total} = Q_1 + Q_2 + Q_3$$

f. Heating Furnace Efficiency

The efficiency of the furnace can be determined by measuring the amount of heat absorbed by the kowi and dividing it by the number of calories used.

$$\text{Thermal efficiency} = \frac{\text{heat in the saucer}(Q_c)}{\text{total heat}(Q_{total})} \%$$

III. RESULT AND DISCUSSION

3.1 Design Results Build a Heating Furnace

The design heating furnace consists of the following components:

a) Heating Furnace

Heating Furnace consists of the base and walls. The base is made using rectangular fire bricks which are cut using a saw and arranged into a circular shape using fire-resistant cement as the adhesive. The base is made for one day and dried by waiting for one night. The base furnace is given a stand to place the crucible as shown in Figure 18.



Figure 18: Base of the Heating Furnace

On top of the base, four fire bricks are arranged to form a square, the corners of which are given a piece of fire brick and arranged upwards. On the outside and inside of the four fire bricks, a circular plate is given as a mold. Then the mold is filled with cement to form the furnace wall as shown in Figure 19. Parts of the furnace wall are made for one day and dried by waiting for one night.



Figure 19: Making Furnace Wall

The furnace consists of refractory stones formed according to the design. Figure 15 shown the design of a heating furnace. The type of furnace is cylinder -shaped with a diameter of 48 cm and a height of 30 cm. and has a combustion chamber diameter of 24 cm x height of 21.5 cm.



Figure 20: Furnace

The weight of the furnace can be calculated by (Adi, Raharjo, and Surojo 2014) :

$$\text{Furnace weight} = \text{Weight}_{\text{firebrick}} + \text{Weight}_{\text{mortar}}$$

$$\text{Weight}_{\text{firebrick}} = \rho \times \text{Volume}_{\text{firebrick}}$$

$$\text{Weight}_{\text{mortar}} = \rho \times \text{Volume}_{\text{mortar}}$$

Information:

$$T_{\text{furnace}} = \pi \times r^2 \times t$$

$$\Pi = 3,14$$

r = radius

t = height

1 kg of cement = 0,7 liter

b) Cover heating furnace

The furnace cover is made using fire brick cut in half thickness and given a steel handle. Then the outer edge is given a circular plate as a mold and filled with cement to form a circle. Then wait for one night to dry.

Dimension of cover consist of two segments. This condition was done to be easy operation for close and open furnace especially to arrange crucible, fuel.

The furnace lid consists of refractory stone formed according to the design. Picture 19 is the design of the heating furnace lid. The lid of the furnace is cylindrical in shape with a diameter of 48 and a height of 3.5 For the middle hole, wait 5 cm in diameter x 3.5 cm in height.



Figure 21: Cover the heating furnace

c) Electrolysis crucible and electrolysis crucible lid

The electrolysis crucible is made of graphite with a size of 12.5 cm with a height of 8 cm. The crucible cap is made from a single fire brick cut into a circular shape with diameter 12.5 cm with a height of 6.5 cm. The crucible cap is drilled to make several holes for 8 mm electrodes, 8 mm and 10 mm supply for argon gas and 10 mm for thermocouple holes. Figure 22 and 23 shows the cap and the electrolysis crucible. The crucible lid is needed as insulation against the air around the furnace.



Figure 22: Crucible electrolysis



Figure 23: Crucible electrolysis cap

d) Control box

The control box is an observation place consisting of several components. There are 2 indicators, namely temperature and voltage control produced by power supply. For temperature control using thermocouple with type K. While the power supply uses a 12 volt adapter plus power up to increase the voltage to 24 volts. Figure 18 shows the control box and its components.



Figure 24: Control box

e) Air Supply

Air supply is divided into 2, namely oxygen air supply and argon gas supply. For air supply to increase the amount of oxygen using a blower with a size of 2 inches. Meanwhile, for argon gas supply using argon gas produced from argon gas tanks with a pressure of 1 atm.

3.2 Heating Furnace Test Result

a) Furnace Test Results

Test 1 performs a test of fuel heating and furnace resistance. Phase 1 testing was carried out by varying the mixture of charcoal and coal. Weight details are shown in table 1.

Table 1: Composition Coal and charcoal

Specimen	Coal	Wood charcoal
	Weight (grams)	
BB1	1000	30
BB2	1000	60
BB3	1000	100

The results of stage 1 testing at the heating level are known that the smelting furnace designed can reach temperatures up to 830°C. The variety of fuel used gets a comparison of the time from the heating process to reach a temperature of 725°C. The fastest time to reach a temperature of 725°C using the BB3 variation is 20 minutes. Time measurement using a stopwatch for temperature can be seen through a control box that has a temperature display. Temperature measurement was done by using thermocouple.

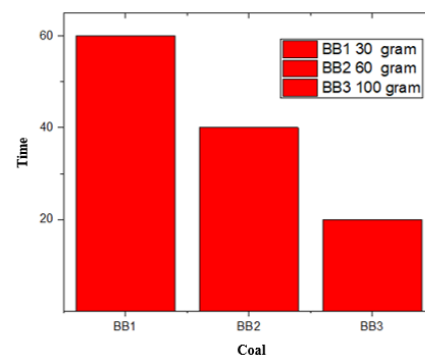


Figure 25: Time comparison

b) Weight furnace

$$\text{Furnace weight} = \text{Weight}_{\text{firebrick}} + \text{Weight}_{\text{mortar}}$$

$$\begin{aligned} \text{Weight}_{\text{firebrick}} &= \text{volume}_{\text{firebrick}} \times \rho \\ &= 23.441 \times 0.8 \\ &= 18,8 \text{ kg} \end{aligned}$$

$$\begin{aligned} \text{Weight}_{\text{mortar}} &= \text{Volume}_{\text{mortar}} \times \rho \\ &= 21.09 \times 0.7 \\ &= 14.76 \text{ kg} \end{aligned}$$

$$\begin{aligned} \text{Furnace weight} &= 18,8 \text{ kg} + 14,76 \text{ kg} \\ &= 33,5 \text{ kg} \end{aligned}$$

c) The specific heat of MgCl₂

$$C_p \text{ MgCl}_2 = \text{solid}$$

$$\text{Solid} = 25^\circ\text{C} = 298,15 \text{ K}$$

$$C_{pMgCl_2} = 76.651 + 9984 \times 10^{-3} \times T - 6439 \times 10^5 \times T^2 - 0.006 \times 10^{-6} \times T^2$$

$$= 723.83 \text{ J/kg.K}$$

$$C_p \text{ MgCl}_2 = \text{liquid}$$

$$\text{Liquid} = 725^{\circ}\text{C} = 998,15 \text{ K}$$

$$C_{pMgCl_2} = 88.141 + 0,002 \times 10^{-3} \times T + 59,212 \times 10^5 \times T^2 = 940.86 \text{ J/kg.K}$$

$$C_p \text{ rata-rata} = (723.83 + 940.86)/2 = 832.34 \text{ J/kg.K}$$

d) The sensible heat energy to raise MgCl material

$$Q_1 = M_{mgcl_2} \times C_{pMgcl_2} \times \Delta T$$

$$Q_1 = 0,1 \text{ kg} \times 832.34 \text{ J/kg.K} \times (T_2 - T_1)^{\circ}\text{C}$$

$$Q_1 = 7,6 \text{ kg} \times 832.34 \text{ J/kg.K} \times (725^{\circ}\text{C} - 25^{\circ}\text{C})$$

$$Q_1 = 58263,8 \text{ J}$$

e) The heat energy used to liquefy MgCl₂

$$Q_2 = M_{mgcl_2} \times h$$

$$Q_2 = 0,1 \text{ kg} \times 454 \text{ J/kg}^{\circ}\text{C}$$

$$Q_2 = 45,4 \text{ KJ}$$

f) The heat sensible on crucible

$$Q_3 = M_{crucible} \times C_{p_{crucible}} \times \Delta T$$

$$Q_3 = 6 \text{ kg} \times 641 \text{ J/kg}^{\circ}\text{C} \times T_2 - T_1^{\circ}\text{C}$$

$$Q_3 = 6 \text{ kg} \times 641 \text{ J/kg}^{\circ}\text{C} \times 725^{\circ}\text{C} - 25^{\circ}\text{C}$$

$$Q_3 = 2692,2 \text{ KJ}$$

f) Heat energy is used to melt MgCl₂ in the crucible

$$Q = Q_1 + Q_2 + Q_3$$

$$Q = 58,263 \text{ KJ} + 45,4 \text{ KJ} + 2692,2 \text{ KJ}$$

$$Q = 2795,86 \text{ KJ}$$

g) Heat loss the furnace cap

$$Q_r = 0,5 \text{ Q}$$

$$Q_r = 0,5 \times 2795,86 \text{ KJ}$$

$$Q_r = 1397,93 \text{ KJ}$$

h) Total thermal energy

$$Q_t = Q + Q_r$$

$$Q_t = 2795,86 \text{ KJ} + 1397,93 \text{ KJ}$$

$$Q_t = 4193,79 \text{ KJ}$$

i) Supply Fuel from Coke

Calorific value of charcoal = 200 Kcal/kg = 836,8 KJ/kg

Calorific value of coal = 8300 Kcal/kg = 34727,2 KJ/kg

Table 2: Heat value from calcoal

Variant	Charcoal Mass (Kg)	Calorific Value (KJ)	Total heat from coal and charcoal (KJ)
A	0,10	83,68	34810,88
B	0,06	50,21	34777,41
C	0,03	25,10	34752,30

Table 2 shown the total value of heat from coal and charcoal. Variant A consist of 0,1 kg charcoal and 1 kg of coal. The total heat is 44810,88 KJ. Variant B was the weight of charcoal of 0,06 kg and 1 kg coal, the total heat of 34777,41 J, while the variant C has the total heat of 34752,30 KJ. The total heat which has been supplied in the furnace will affect the time melting of MgCl₂. This condition can be seen in the Figure 25.

3.3 Electrolysis test results

Phase 2 testing is an electrolysis test of magnesium chloride weighing 100 grams. Electrolysis testing is carried out by varying the voltage used, namely 12 volts and 24 volts.

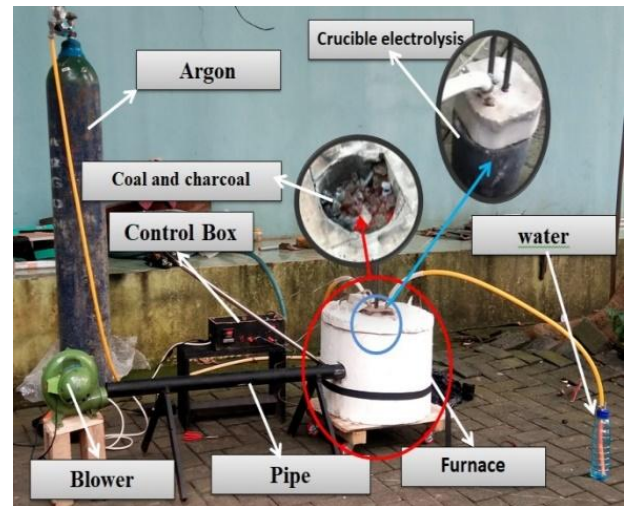


Figure 26: Design results

Table 3 is a description of magnesium chloride specimens with voltage ratios. Sp1, Sp2, and Sp3 is the result weight from the electrolysis process.

Table 3: Specification specimen

Specimen type	Electric Voltage	Weight MgCl ₂ (grams)
Sp1	0 volt	100
Sp2	12 volt	100
Sp3	24 volt	100

Figure 11 is the result of the electrolysis process for heavy bandage with voltage differences. The process of electrolysis occurs weight loss shown in figure 11. Sp2 produces a weight of 19.5 grams after electrolysis with a voltage of 12 volts while for Sp3 produces a weight of 14.1 grams with a voltage of 24 volts.

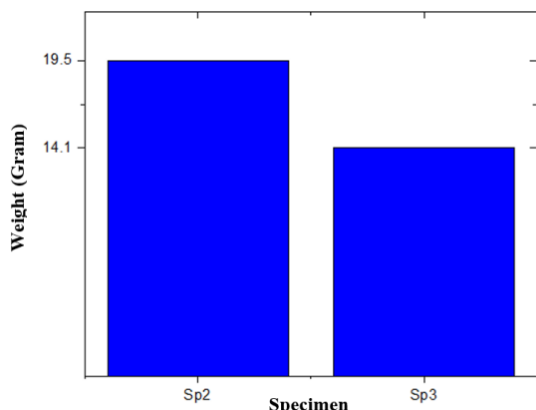


Figure 27: Electrolysis weight comparison

The results of the electrolysis process are characterized using XRF. The results of characterization using XRF get the results shown in table 4. Sp1 is the result of characterization of magnesium chloride without electrolytion. Sp2 is the result of characterization of magnesium chloride after electrolysis with a voltage of 12 volts. Sp3 is the result of characterization of magnesium chloride after electrolysis with a voltage of 24 volts. Based on the results of XRF there is a decrease in Mg, Cl, and Ca levels the greater the voltage applied; there is a decrease in Mg and MgO levels.

Table 4: Characterization result of electrolysis

Specimen type	Result element (%)		
	Mg	Cl	Ca
Sp1	41,8	40,2	9,22
Sp2	39,9	42,3	9,21
Sp3	5,9	87,4	5,23

IV. CONCLUSION

The results of the design and testing of heating furnaces used for the electrolysis process with a temperature of 725⁰C that have been carried out, it can be concluded that the design and manufacture of heating furnaces for the electrolysis process are made according to their design. Designed heating furnaces can be used up to temperatures of 800⁰C. The heating furnace is made of refractory stone and refractory cement and is given air circulation using a blower. Electrolysis crucible with graphite material and cover using refractory stone given holes for argon gas supply, electrodes and thermocouple placement.

The fuel used uses a mixture of wood charcoal and coal. The most efficient time to reach a temperature of 725⁰C using a variation of 100 grams of wood charcoal with 1000 grams of coal can be reached in 20 minutes. The result of the electrolysis process, the higher the electric voltage given, the lighter the weight of the specimen carried out by the electronics.

The difference in time of melting salt of MgCl₂ was caused by supplying of the heat from coal and charcoal.

REFERENCES

- [1] Adi, Ismail Mukti, Wahyu Purwo Raharjo, Eko Surojo. 2014. "Rancang Bangun Tungku Pencairan Logam Aluminium Berkapasitas 2 Kg Dengan Mekanisme Tahanan Listrik Pengujian Performansi" 13: 21–32.
- [2] An, Gang, Yinghui Wang, Wei Li, and Jing Liu. 2012. "Research on Key Designing Parameters of Destruction Furnace for Explosive Waste." *Procedia Environmental Sciences* 16: 202–7.
- [3] Bono, Wahyono, and Muhamad Burhani S. 2017. "Analisis Konsumsi Batubara Spesifik Ditinjau dari Nilai Kalor Batubara and Perubahan Beban di PLTU Tanjung Jati B Unit 2." *Eksergi Jurnal Teknik Energi* 13(2): 50–53.
- [4] Demirci, Gökhan, and Ishak Karakaya. 2012. "Molten salt electrolysis of MgCl₂ in a cell with rapid chlorine removal feature." *Magnesium Technology*: 59–62.
- [5] Güden, M., and I. Karakaya. 1994. "Electrolysis of MgCl₂ with a top inserted anode and an Mg-Pb cathode." *Journal of Applied Electrochemistry* 24(8): 791–97.
- [6] Handaja, Suka, Heru Susanto, and Hermawan. 2020. "Electrical conductivity of carbon electrodes by mixing carbon rod and electrolyte paste of spent battery." *International Journal of Renewable Energy Development* 10(2): 221–27.
- [7] Haruna, Abdullahi I., R. Sankar, and Abdullahi Y. Mohammed. 2022. "Design and construction of gas and charcoal-fired crucible furnace." *Materials Today: Proceedings* 52: 2031–35.
- [8] Hirsch, J., and T. Al-Samman. 2013. "Superior light metals by texture engineering: Optimized aluminum and magnesium alloys for automotive applications." *Acta Materialia* 61(3): 818–43. <http://dx.doi.org/10.1016/j.actamat.2012.10.044>.
- [9] Ibrahim, Gusri Akhyar et al. 2017. "Analisa Keausan Pahat Putar pada Pembubutan Magnesium AZ31 Menggunakan Udara Dingin Bertekanan." : 10–14.
- [10] Istana, Budi, and Japri Lukman. 2016. "Rancang Bangun and Pengujian Tungku Peleburan Aluminium Berbahan Bakar Minyak Bekas." *Jurnal Surya Teknika* 2(04): 10–14.
- [11] Jung, H, L Yang, and T Ahn. 2011. "An Electrochemical Study On Passivation Of Alloy 22 In Chloride-Containing Solutions With And Without Sulfur Prepared for Prepared by Center for Nuclear Waste Regulatory Analyses San Antonio , Texas U . S . Nuclear Regulatory Commission." (September).

- [12] Kennedy, Mark, and Ralph Harris. 2012. "Chlorination of Magnesium Carbonate in a Stirred Tank Reactor." *Canadian Metallurgical Quarterly* 39(3): 269–80.
- [13] Kipouros G.J., and Sadoway D.R. 1987. "The chemistry and electrochemistry of magnesium production." *Advances in Molten Salt Chemistry* 6 (January): 127–209.
- [14] Martínez-Rivero, María Dolores, Pedro Hernández-Castellano, María Dolores Marrero-Alemán, and Luis Suárez-García. 2019. "Manufacturing process selection integrated in the design process: Test and results." *Procedia Manufacturing* 41: 827–34. <https://doi.org/10.1016/j.promfg.2019.09.075>.
- [15] Mubarak, Amir Zaki, and Akhyar. 2013. "Perancangan and Pembuatan Dapur Peleburan Logam dengan Menggunakan Bahan Bakar Gas (LPG)*." *Jurnal Teknik Mesin Unsyiah 1(Juni)*: 128–32.
- [16] Peng, Yuxiang. 2016. "Advances in Molten Slags, Fluxes, and Salts: Proceedings of the 10th International Conference on Molten Slags, Fluxes and Salts 2016." *Advances in Molten Slags, Fluxes, and Salts: Proceedings of the 10th International Conference on Molten Slags, Fluxes and Salts 2016* (January 2016).
- [17] Shih, Yu Jen, Chia Chi Su, and C. P. Huang. 2015. "The synthesis, characterization, and application of a platinum modified graphite electrode (Pt/G) exemplified by chloride oxidation." *Separation and Purification Technology* 156: 961–71.
- [18] Wulandari, Winny, Geoffrey A Brooks, Muhammad a Rhamdhani, and Brian J Monaghan. 2008. "Magnesium: Current and Alternative Production Routes." *Chemeca 2010: Engineering at the Edge*; 26-29 September 2010, Hilton Adelaide, South Australia (August): 347.

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