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RUHR-UNIVERSITÄT BOCHUM

**MechEng**  
Mechanical Engineering



Vietnamese-German University

**TOPIC**

**DESIGNING AND  
PROGRAMMING FOR  
BATTERY SPOT WELDING  
MACHINE**

**BACHELOR THESIS**



Vietnamese-German University

PLACE 2023

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# DESIGNING AND PROGRAMMING FOR BATTERY SPOT WELDING MACHINE

A Thesis Presented by

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Submitted to the Examination Board RUB University Bochum,

Vietnamese - German University

in fulfillment of the requirements for degree of

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DESIGNING AND PROGRAMMING FOR BATTERY SPOT WELDING MACHINE



Approve by:

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## ABSTRACT

Small steps that lead to the welding industry was first made in the early 1800 when Sir Humphry Davy composed the first electric arc between two carbon electrodes by the use of a battery. Following that, until 1836, Edmund Davy a British chemist found out about Acetylene, a welding gas which helps during the procedure. But not until 1881, the process which we called “welding” was recognized. It started when **Auguste de Méritens**, a French electrical engineering of 19<sup>th</sup> century, and his student used arc heat to join different types of material such as lead or carbon rods. In the beginning of 20<sup>th</sup> century, thermite welding was first emerged [1]. With the discovery of C.J. Holslag in 1919, an alternating current welding was invented and replaced the old electric arc welding. And from that, it kept continue to increase in both technique and high demand to served different purposes of human [2].

Welding has become one of the most crucial industry in the era of civilization. It contributes directly to a variety of manufacturing industries such as automobile, telecommunication, airplane and so more. Due to its wide range of applications, welding has developed into different types in order to be suited for a variety of products. Gradually, from products in large scale, welding has also been developed so we can apply it to smaller scale products such as cellphones, microchips, electrical parts and many more.

With the development personal items such as laptop, backup charger. In this research, a conceptual design of a spot welding machine is generated in order to create mechanical parts to minimize the manufacturing costs and use the materials which are already available for modification and program the machine.

## ACKNOWLEDGEMENT

As my research and prototype design to be succeeded, I would like to express my greatest gratitude to my supervisor Dr. Tran Trung Thanh for your great support. Your enthusiastic spirit motivated me during the time of the making of this project and your way of teaching always making me feel warm and welcomed in Vietnamese German University.

Also, this thesis would not be possible without the massive support from the engineer at Vietnamese German University laboratory and also my second supervisor, Mr. Nguyen Phat Tai. At the beginning of this thesis, I was like walking through thick fog, but with your fantastic support as well as your contribution during the ideation and manufacturing of the product, everything is clearer for me and finally, I could find myself walking on the right track.

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## Chapter 1: Introduction about Spot Welding Machine.

The project's goal is to design and program a small scale spot welding machine, which can be used to attach battery cells together with an affordable cost and easy to understand mechanism which is suitable for school's project and household usage. Based on those requirements, the mechanical design and programming for the machine will follow around these goals.

### 1.1. Spot welding definition.

Spot welding (also known as resistance spot welding) which is used to join metal sheets together by applying pressure and electric current to the spot weld area. This welding method was invented in 1885 when Elihu Thomson, an American engineer accidentally joined 2 copper wires together during his experiment [3].

By applying pressure (pressing or squeezing) together with the heat which is generated by the electric current that goes from 1 tip of the electrode to the other electrode, the material will be melted and fused together over a small area and finally, a welding joint is formed.

The amount of heat generated in spot welding is expressed by the heat-energy formula:

$$Q = I^2 R t$$

With:

- **Q** is the heat energy,
- **I** is the current,
- **R** is the electrical resistance,
- **t** is the time which the current is applied.

### 1.2. Advantages and disadvantages of spot welding.

With a hundred of years of development, resistance spot welding technique has developed with different improvements:

- Spot welding is one of the fastest and environmental friendliest methods.
- Easy to understand and straight forward process.
- No open flame.
- The process is easy to be automated through the use of welding robots.
- Can join multiple metal sheet at the same time.
- No need for filler material.
- Does not need inert gases or filler metal therefore, it is cost-effective and economical.

However, there are some remain difficulties while using this technique:

- The work piece must be aligned with high precision.
- The base metal will be deformed after weld.
- Have to consider the thickness since it cannot weld too thick material.
- RSW only create localized joints therefore, it would not be as durable as other welding method.
- Have to calculate the suitable pressure or it will result in a low-quality weld.
- Shunting may happen with different type of materials.
- Electrode's tips may crack due to overheat.
- Spatter may occur with poor handling and wrong parameters.

### **1.3. Types of resistance spot welding**

After more than hundred years of development, there are many ways of spot welding has been developed and put into use. The most famous of them are Spot welding and Seam welding.

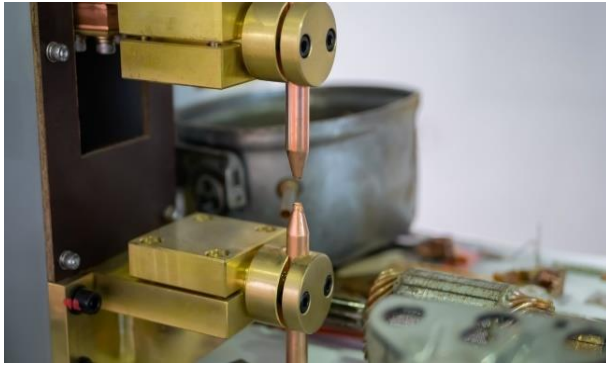


Figure 1: Spot welding electrodes



Figure 2: Seam welding electrodes

Overall, the working mechanism of these 2 variants are alike. By letting the AC power source running from the anodes through the materials, the machine will be able to join the work pieces together.

The one particular difference lies in the shape of the welding joint. While the shape of the weld nugget of the spot welding looks like a large spot of melting metals, the shape of a seam welding is a long line of a melting metals that fused into each other.

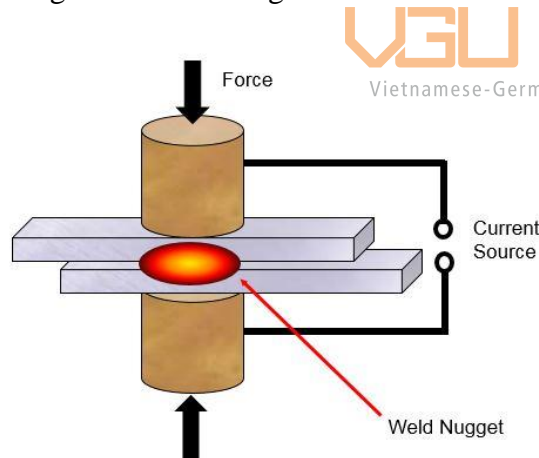


Figure 3: Spot welding nugget.

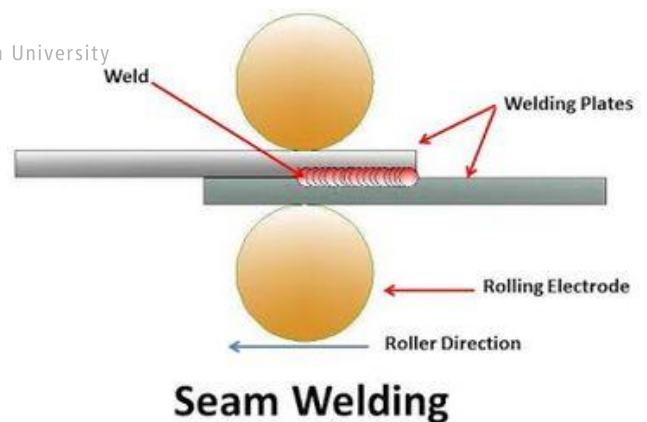


Figure 4: Seam welding nugget

As presented in the introduction, the main goal of this project is to find out the most suitable design for small industry structure as well as in the laboratory for school's project. Therefore, this thesis will focus strongly on the design for the spot welding only. Later on when gather enough experimental data, a development into seam welding design will be made.

## 1.4. Components and working mechanism.

### 1.4.1. Mechanical parts

A spot welding machine contains of 4 important part, which are:

- Welding power supply.
- Welding transformer.
- Welding head.
- 2 welding anodes.

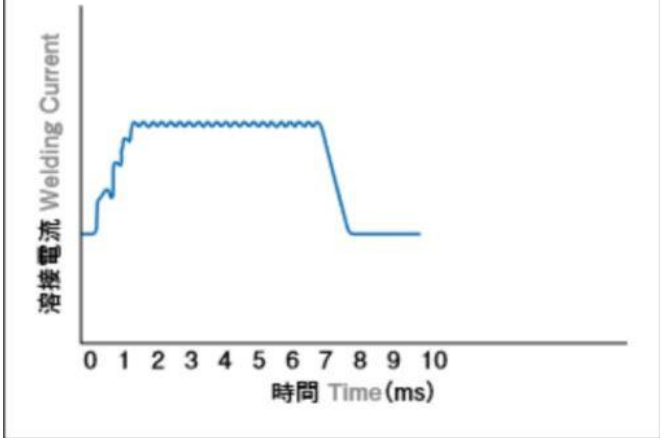
#### Welding power supply:

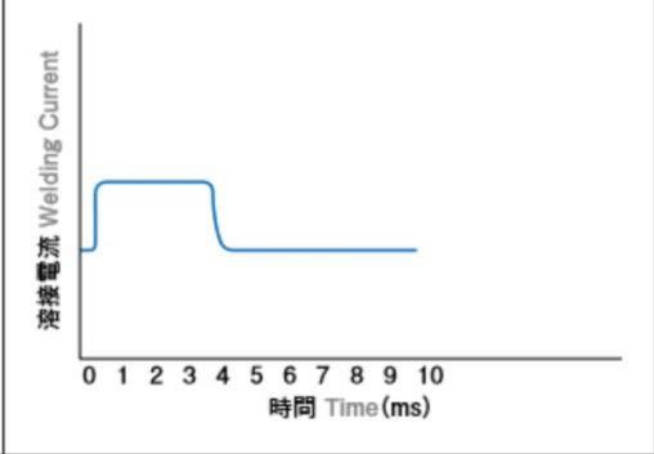

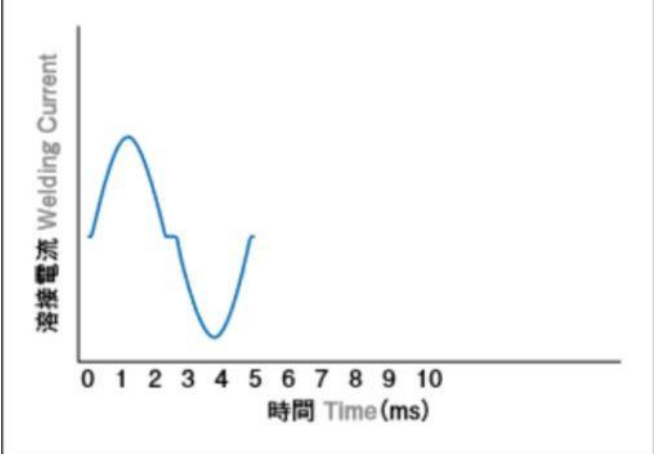
In general, this part of the machine take responsible for controlling the magnitude, time and waveform of electric current. Based on the materials, the shape of the object must be welded and the quality of the welding nugget. There are about 5 types of basic system with different kind of welding current wave form. Each system will be suitable with different kind of material for different purpose.

Below is a table that shows the differences in the waveform and features for each system [4].

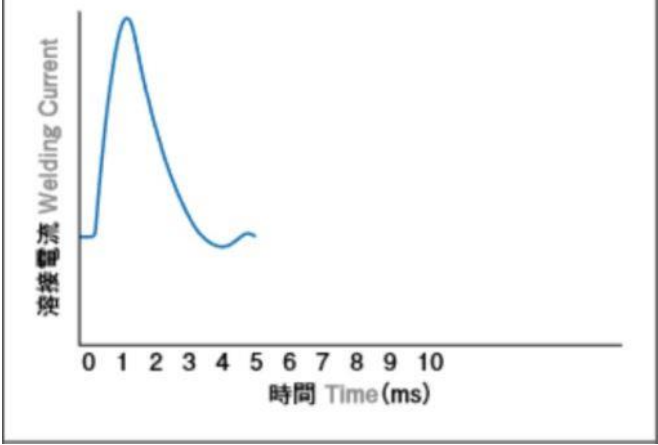

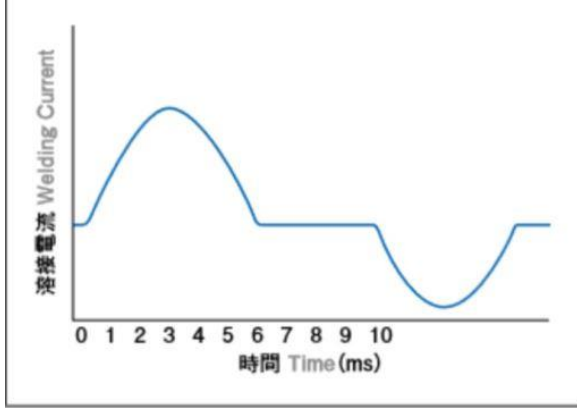


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Basic system	Welding current waveform	Feature
Inverter type	 <p data-bbox="711 1661 1036 1688"><i>Figure 5: Inverter type waveform</i></p>	AC current is transformed into DC current. Due to high frequency, heat efficiency is good and suitable to precision welding. Stable welding quality can be expected because of the electric current and voltage feedback control.

		As high speed repetitive welding can be made, it is suitable for use in automated systems.
Transistor type	 <p style="text-align: center;"><i>Figure 6: Transistor type waveform</i></p> 	Electric current is controlled by a transistor. Because the control speed is fast and the waveform can be controlled, it is suitable for high precision welding of very small components or fine wires.
Hybrid (DC + inverter) type	 <p style="text-align: center;"><i>Figure 7: Hybrid type waveform</i></p>	Polarity of a large current is switched in high speed by a power transistor. It is called hybrid due to the high speed feature of DC and polarity switching feature of AC power supplies. It is suitable for welding of battery tabs where different kind



		of materials are series welded
Capacitor (DC) type	 <p style="text-align: center;"><i>Figure 8: Capacitor type waveform</i></p> 	Electric is charged into a capacitor and discharged at once. Because a large current can be applied, this type is used for material with good heat dissipation characteristic and difficult to weld like aluminium or copper. And due to short welding duration, heat impact is minimize, as a result, it is suitable for welding of small components.
Single phase (AC) type	 <p style="text-align: center;"><i>Figure 9: : Single phase type waveform</i></p>	Welding current is controlled by thyristor because the welding duration can be made long, it has a broad application, and it is suitable to a material which is

		relatively easy to weld such as iron.
--	--	---------------------------------------

After the consideration for control method, it is important to find out a suitable welding power supply which carry the appropriate current capacity depending on the size and thickness of the object to be welded.

**Welding head and electrodes:**

There are four basic type of welding head. Those are: **opposed type**, **indirect type**, **series type** and **parallel gap type**. Which type of welding head and electrodes to be used is determined by the shape or the structure of the object. Below are introduced types of electrodes [5]:

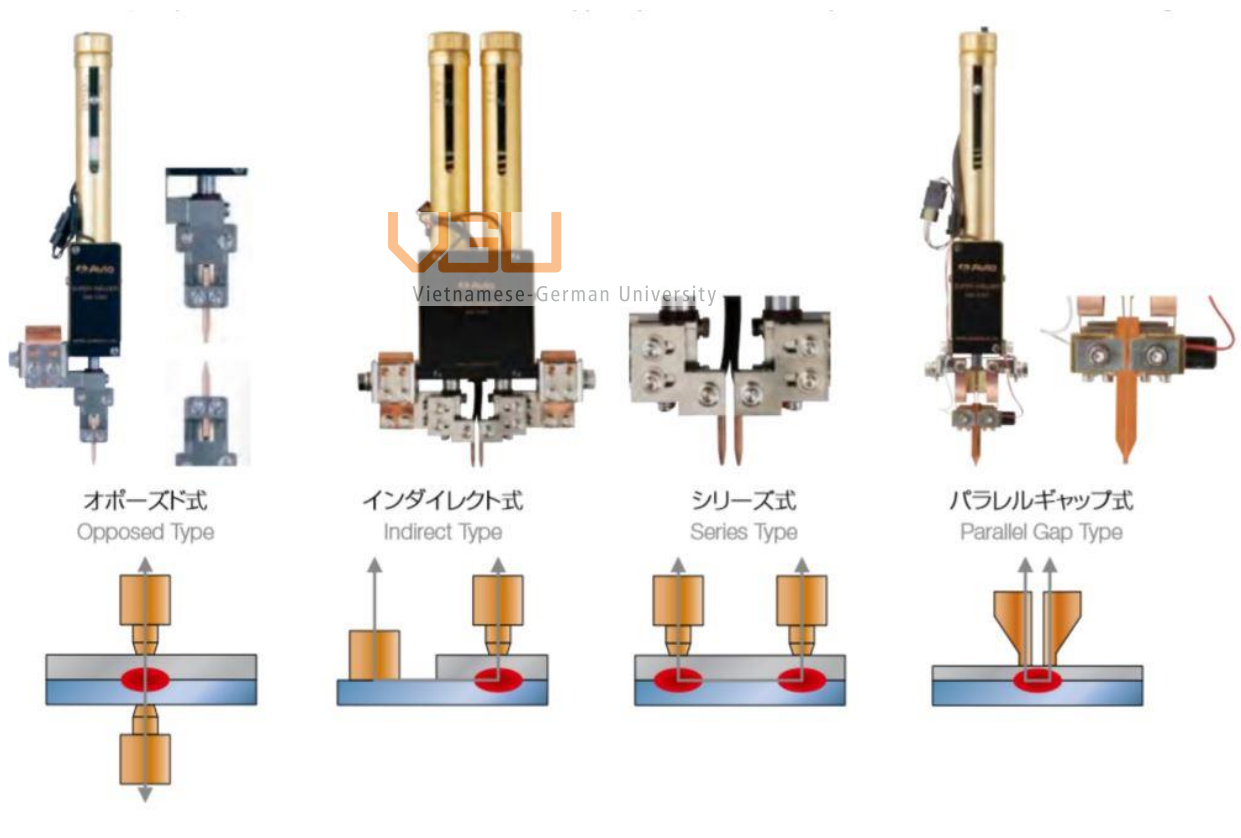
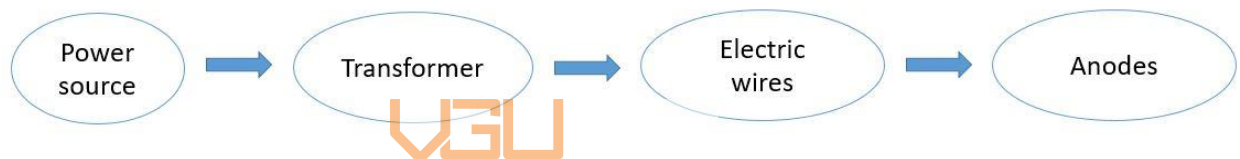


Figure 10: Different types of electrodes.

As the main goal for this project is to weld the battery tab, I will use the series type because 2 electrodes are parallel and have a suitable gap. The parallel gap type also has 2 electrodes with the same properties. However, the gap between them is too small and may affect the welding nugget for the object. By using the series type, we can make modification so the gap between 2 anodes can be changed whenever it needs in the future.

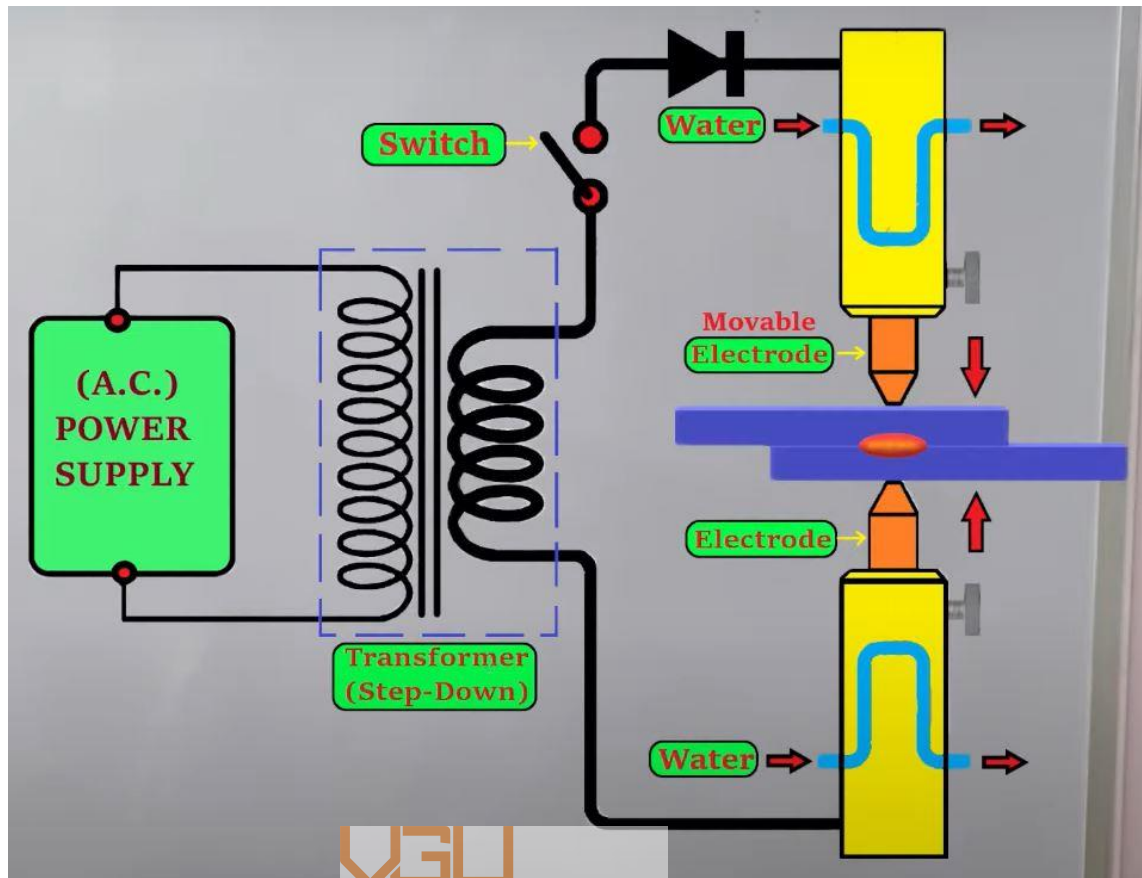
#### ***1.4.2 Working mechanism.***

There are not too much steps when a spot welder is put into use, it is quite simple since this is a straight forward process. First, the AC power source will supply the energy into the system. The power is then run through the transformer to step-down the voltage. The electricity is then going through the main system and the machine will be activated by a switch. The work flow can be described as below.



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*Figure 11: Work flow of a spot welder.*



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 Figure 12: Working diagram of a spot welder.

For resistance spot welding machine, it is important to have a method which is used to cool down the welding electrodes or it will affect the electrodes and the quality of the welding nugget. The commonly used methods are air or water. However, for this project a system which contains a cooling system is not necessary since welding the battery tabs together does not require the electrodes to work for a long time. However, it is necessary for the machine to have a resting time between each use.

## Chapter 2: Conceptual design.

The main purpose of this project is to design and program a spot welding machine which can help student to have a better understanding in resistance spot welding. Also, this machine should be able to support small project with a reasonable and affordable cost. Base on the given goals, our machine will be developed around these goals.

### 2.1. Introduction

This is our first encounter with this topic. The references for the spot welding machine that we used are mostly made for big industries such as automobile and aircraft. Moreover, the design for small resistance spot welding machine is usually simple, which contain a power source, a transformer, wire and electrodes as shown below.

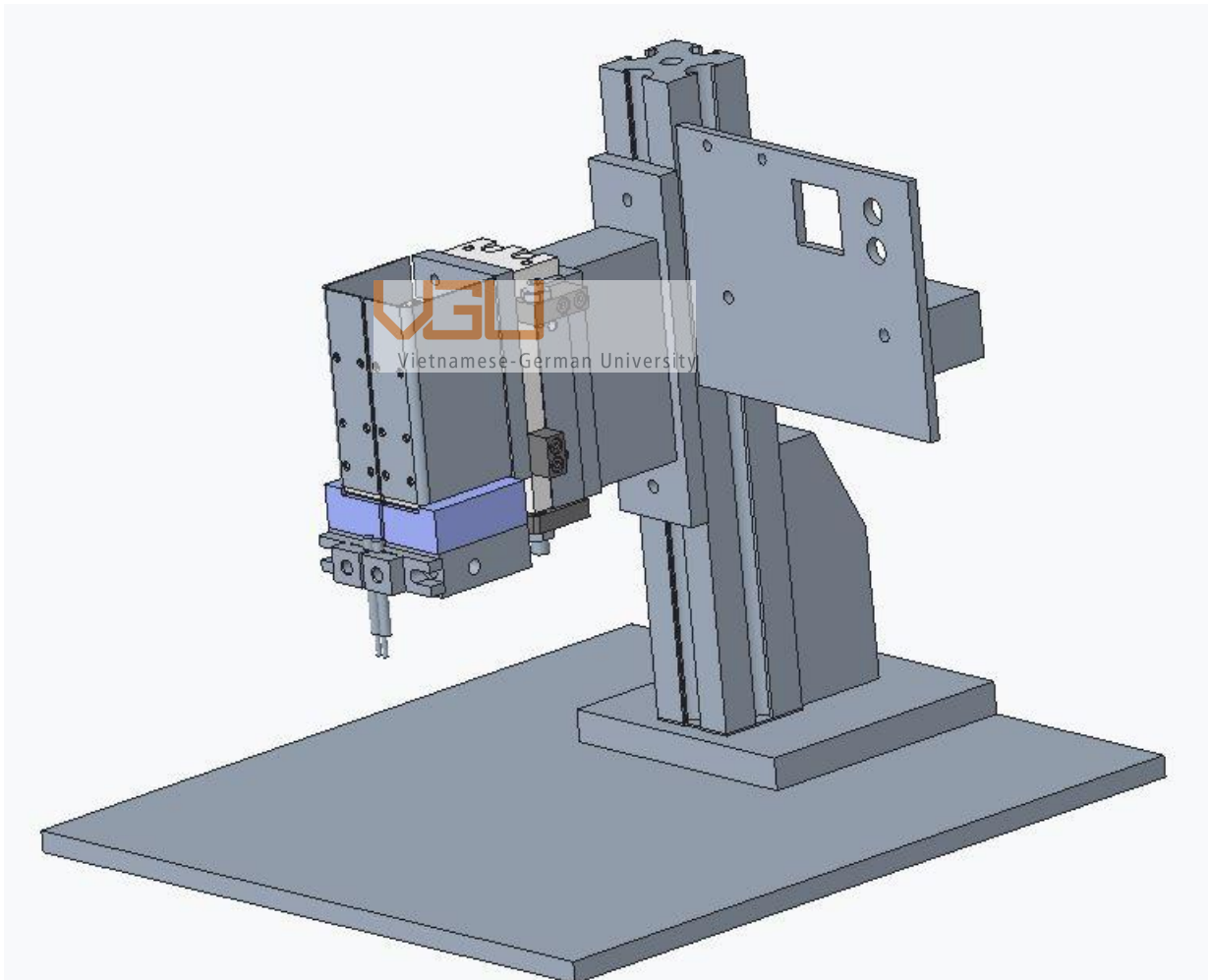


Figure 13: Small spot welding machine.

The design that we are aiming to is a machine which can operate mostly on its own with the least impact from the operator, which means the operator will help in aligning the specimens and

adjusting the electricity current as well as the pressure and welding time. And because this machine is a small one, it needs only 1 person to operate this. Due to the “straight forward” design of the machine, operator can get used to the system and with the simple system design, manufacturing and maintaining cost would be affordable.

To make it easier for instruction, I made a simple 3D model for the spot welding machine with the help from my second supervisor, Mr. Nguyen Phat Tai. This 3D design is an overview for the machine, I will show it in the normal view and exploded view. In the exploded view, the machine will be divided into 7 main parts and from that go deeper into the additional details. Below are the figures for the normal view of the spot welding machine.



*Figure 14: Normal view*

Beside knowing what is the functions of the machine, customers tend to focus on additional details of the design, such as: Moving Limitation, Mass, Repeatability, Functionality. The Moving Limitation of the machine is only considered for the transmitter with the anodes installed since the whole structure of this spot welding machine is idle.

- Moving Limitation:

As mentioned, the moving direction of this device is basically in vertical of the transmitter. Since it is better and easier for the anodes to exert the pressure from above of the work pieces. By making contact from above, those properties such as pressure and time are easier to keep in control.

- Mass:

The mass of the machine is reasonable so it would be easy to for operator to move around, normally with a trolley is enough. The maximum weight of the machine is roughly about 20kg which is contained the main mechanical parts. For additional part, the total weight would be about 30kg.

- Repeatability:

Repeatability is used to describe the ability of the machine to finish a product and then return to the original position, which is call a working cycle. For this project, the machine needs about 0.01 to 0.63 seconds to operate. However, it still needs some time to cool down or the anodes will be defected due to long time of operation.

- Functionality:

The machine is an idle design with moving transmitter. The main purpose of this machine is to weld the battery packs together through a thin panel made from nickel. The difference between this and different types of self-made machine is it has an auto mechanism that works by air and electrical parts. Others tend to be run by hands. With the help of the pressure made from air, it will achieve better stability.

## 2.2 Mechanical design

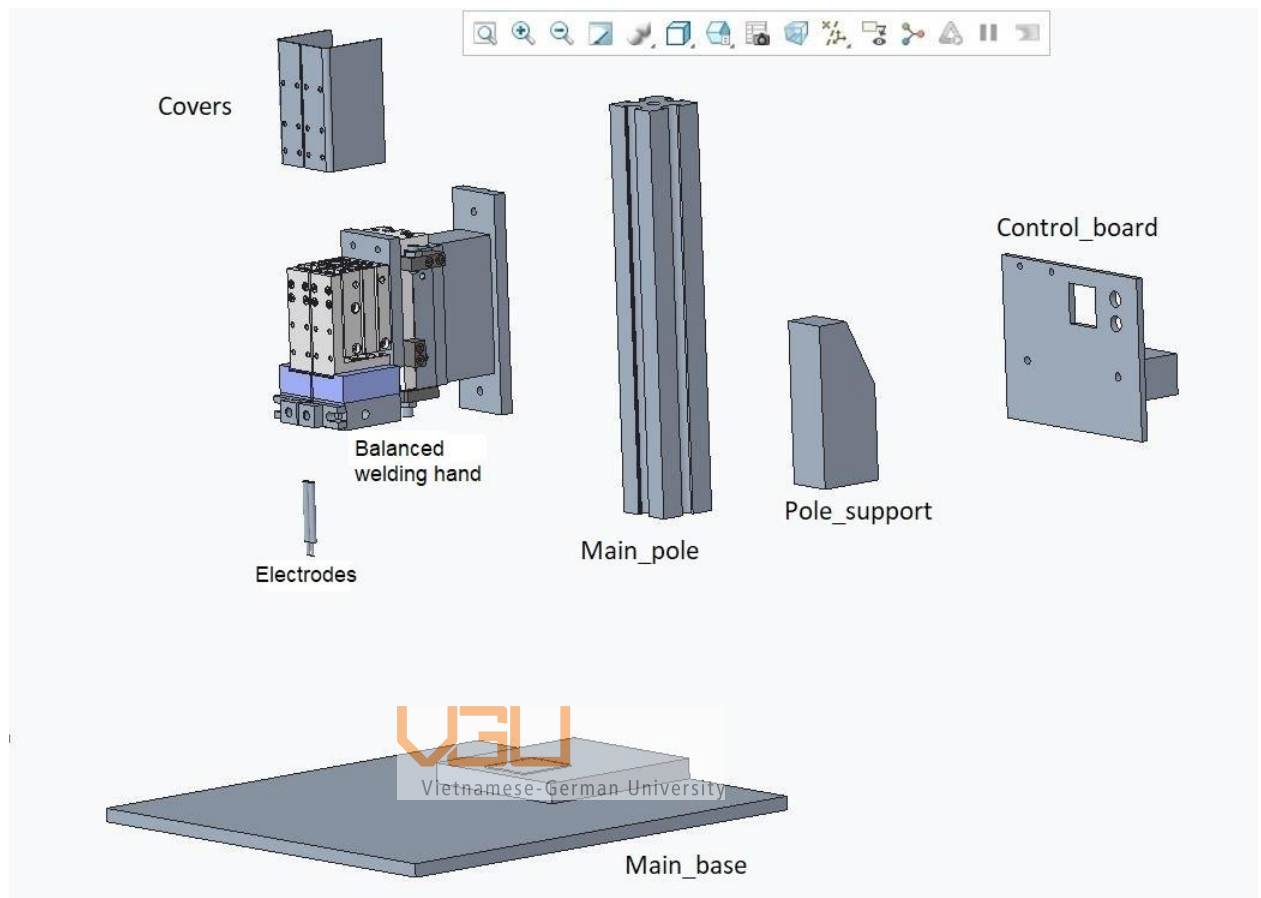


Figure 15: Exploded view of the spot welding machine

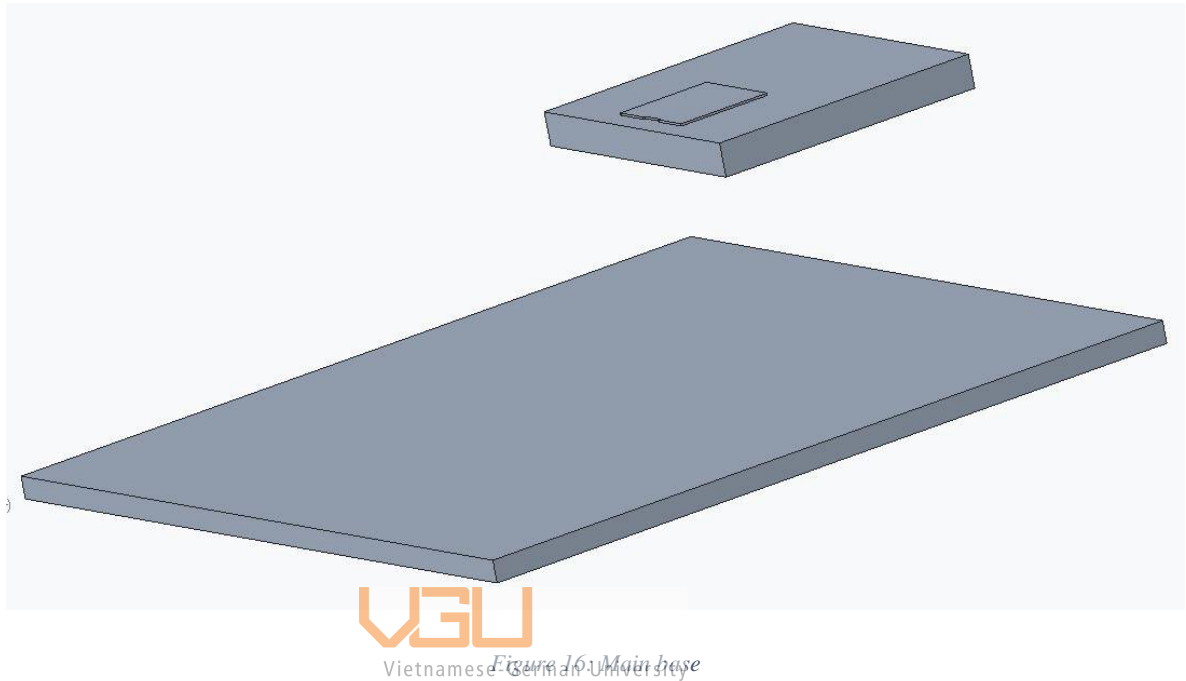
Due to the complexity in the mechanical parts, wires and circuit board of the spot welding machine, it would be easier for visualization by dividing the machine into 7 main parts. Figure 14 shows the exploded view of the spot welding machine. As shown in the figure, the main parts can be seen as:

- Main base.
- Pole support.
- Main pole.
- Electrodes.
- Balanced welding hand.



- Covers.
- Generator.
- Control board.

### 2.2.1. Main base



The total weight of the machine is weighted about 15kg; therefore, a strong base is necessary. This base was made from aluminum. Because the main system is attached to a pole, so the main must have suitable parameters. There are also 2 parts of the main base as shown in Figure 17. The bigger plate acts as a support, also when weld, this plate acts as a working table since the specimen can be put on this plate and be welded on it.

The second square plate acts as a support for the main pole. The reason why we choose to added one more layer is because of the stability it will add when a vertical pole is attached to this.

Two plate will be attached to each other by using M5 hexagonal bolts sink. By using this type of bolt, the installation will be easier and by sinking the bolt into the plate, there will be no exceeded part that make the plate unbalance.

General parameters of plates:

First plate:

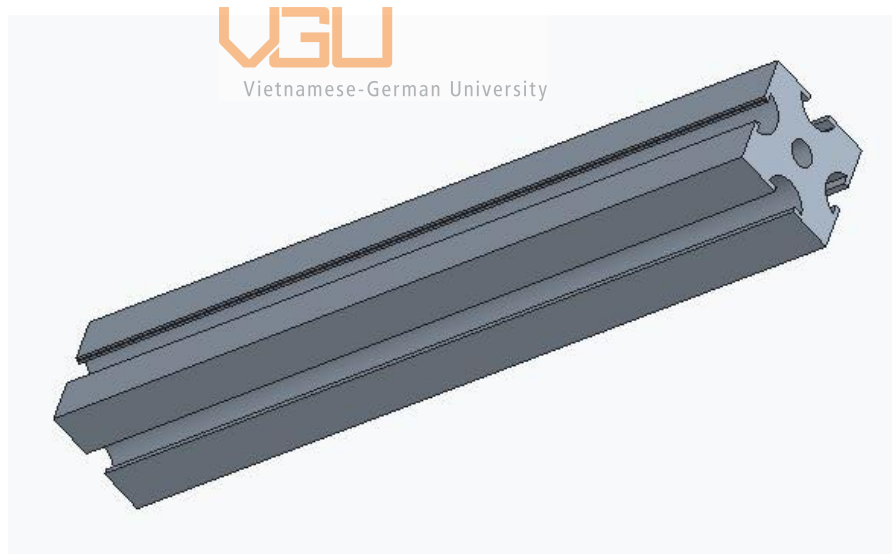
- Length: 350mm
- Width: 350mm
- Height: 10mm

Second plate:

- Length: 130mm
- Width: 130mm
- Height: 15mm

### ***2.2.2. Main pole***

The main pole consists of only one component which is shaped aluminum. This pole is chosen to hold the whole system of which responsible for main function of this machine.



*Figure 17: Main pole*

At present, choosing the shaped aluminum pole is the best choice because of the small trench that it has. This trench acts as a small road so the transmitter can be easily attached and enforced onto it.

General parameters of the main pole:

- Length: 45mm
- Width: 45mm
- Height: 300mm

Additional information of this shaped aluminum such as the rounded corners, hole diameter will be shown as below figure.

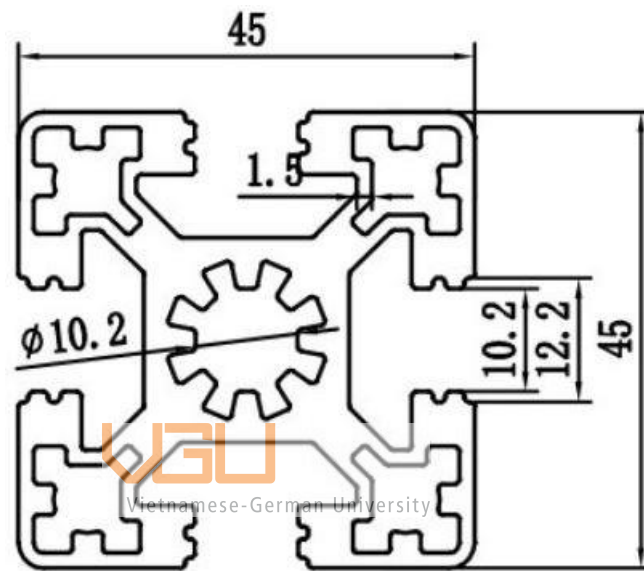


Figure 18: Additional parameters of the shaped aluminum main pole

### 2.2.3 Pole support

As the main system of the whole machine focus on the top of the main pole, the structure tends to be bended forward and for a long run, this downside will cause the machine to be defected. By adding a support that connect the main pole with the base, the weight on the top will be reduced.

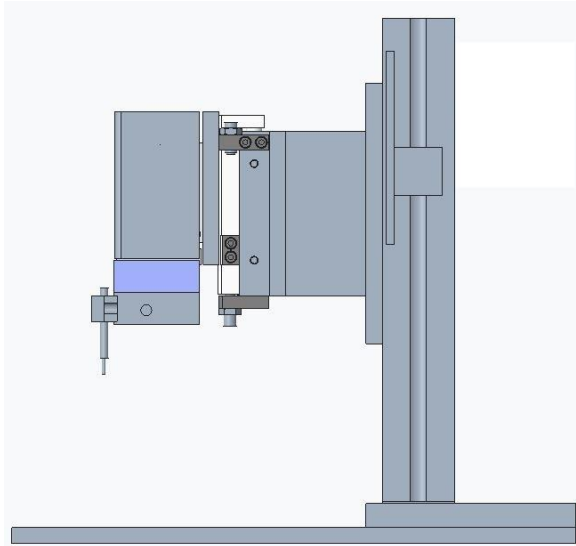


Figure 19: Without support

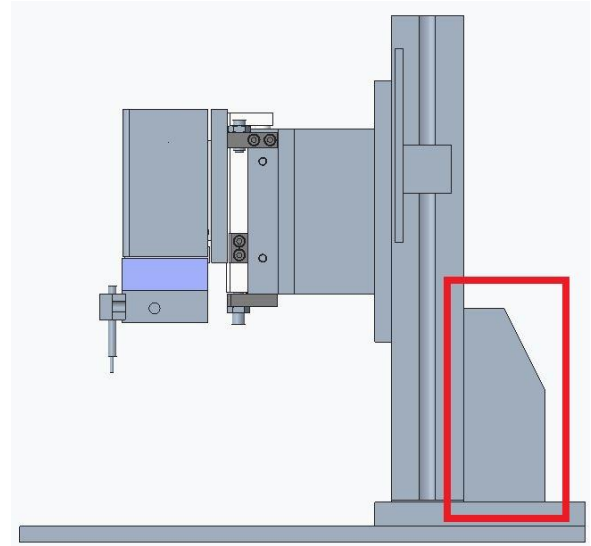
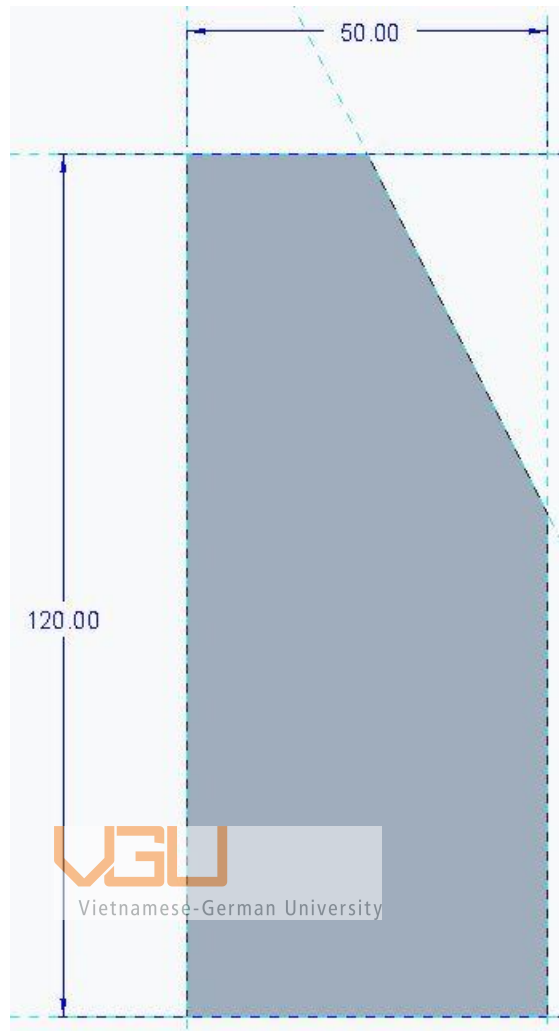


Figure 20: With support

As illustrated in Figure 20, the weight of the transmitter tends to bring the system forward. After a long time, it will make the system defected. This may affect the final products due to the error in pressure and distance from the anodes to the work piece. By adding a support to the back of the main pole and attach it to the base, the pull down force which is made from the transmitter set will be reduced and increase the life time of the machine as well as keep the quality of the acceptable. This support with the main pole as well as the base will be attached together by M5 hexagonal bolts. The design of the support is easy to be manufactured, below is the basic information of the detail.



*Figure 21: Support's parameters*

## **2.2.4 Electrodes**

Electrode plays an important role in spot welding machine. This part will create heat by letting electric current run through the anodes, melt the material and make them stick together.

Electrode materials are covered by ISO 5182 which are mainly copper alloy with a small amount of alloying element to improve hardness but still keep a good conductivity.

To make them fit with the holder of the machine, the diameter of the electrode will be 5mm while the total length will be 54mm. The tip of the electrode will be 10mm long with the diameter 2.4mm.



*Figure 22: Electrodes*

The usual mistake for beginners when making the electrodes' tip for battery spot welding is to make the surface flat. However, by making the flat surface, the contact area between the electrodes and work pieces will be large. When welding, the heat generated from the tip may cause the final product to have small dent, which will make the tabs that used to attached the battery together fall out during long time used. To fix this problem, the heads of the electrodes should be filed so it will have a curve end, this curve will make the welding nugget bends down and helps the materials melted into each other easier and hard to break.



Figure 23: Electrode tip's shape.

There are also 2 types of electrode sets, non-balanced type and balanced type.

#### 2.2.4.1 Non-balanced type



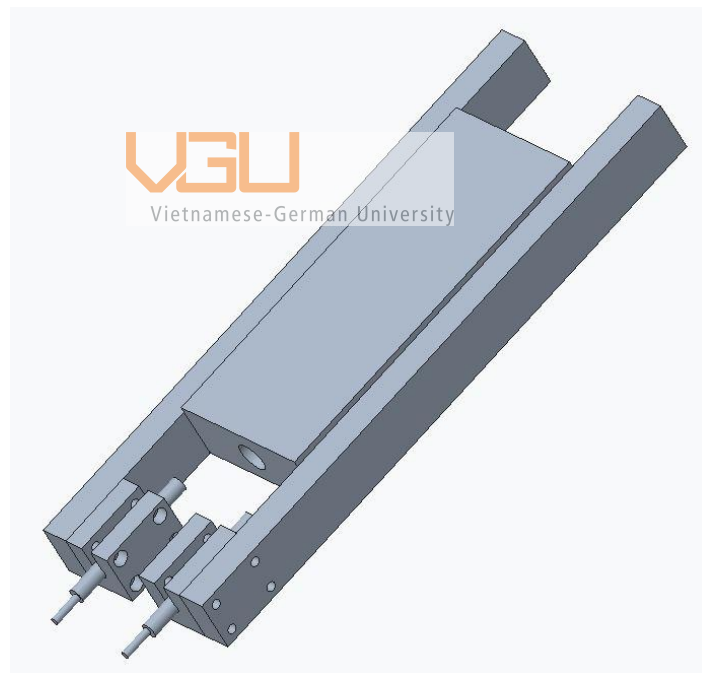
Figure 24: Handed welding electrodes

- The unbalanced type is a simple 2 electrodes which will be hold by user and they will place it on top of the work pieces and weld them together by hand. The 2 electrodes are connected directly to the power source. When activated, the electric current will run

through specimens during selected time. One convenience of this is it would be easier and the design will be more simple since it does not require much modification. However, the disadvantage is users need to hold down the electrodes head to weld and it may result in the difference of the force on each nugget which will lead to small defects of the welding joints.

#### ***2.2.4.2 Balanced type***

Conceptual design for the balanced welding electrodes is a combination of mechanical parts and spring which will help to distribute the force evenly on electrodes. This helps prevent the unbalance force distribution that is caused when weld by hand. Below figures will show the conceptual design of the welding set in normal view and exploded view for better illustration.



*Figure 25: Overall design of welding hand.*



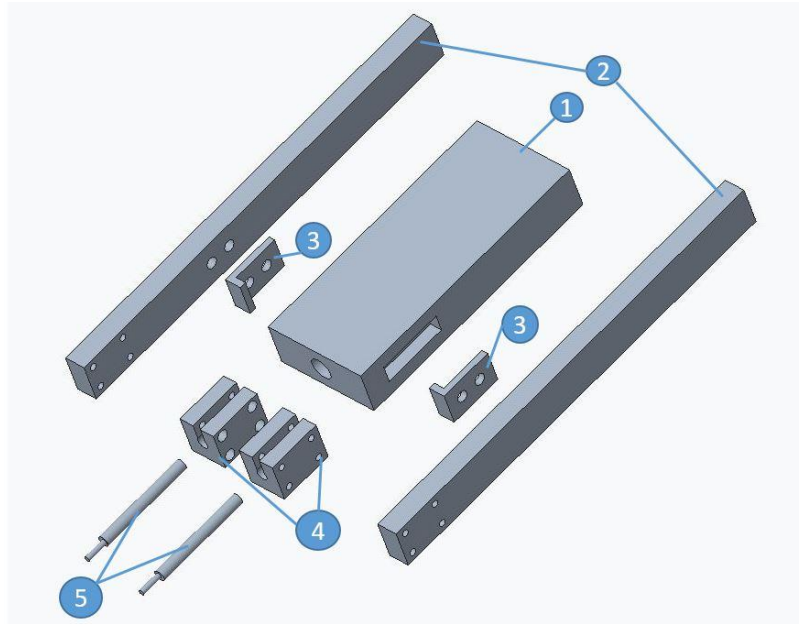


Figure 26: Exploded view of welding hand.



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The design of the auto-balance welding hand is divided into 5 parts:

Table 1: BOM of Balanced welding hand.

Part number	Part Name	Quantity
1	Body	1
2	Pillar	2
3	L Shaped Pin	2
4	Electrode Clips	2
5	Electrode	2

The part that is used as the base for this assembly is part number 1. On two side, there will be 2 2 rectangle holes with the depth is 6mm. The purpose for this feature is to make room for the spring with the diameter of about 5.5mm. In side this part is a through hole with diameter is 10mm which is made for source line. The overall parameters for this part is:

- Length: 120mm

- Width: 50mm
- Height: 20mm

Part 2, 3 and 4 are combined together, and from this, we will attain an electrode holder with an L Shaped Pin. The L Shaped Pin acts as a hinge together with the spring that is put inside the rectangle holes of the body will acts as a suspension mechanism as well as distribute the press force evenly when the system is put in use.



*Figure 27: Assembly of auto balance force rod.*

However, the first design still contains some defects that will not fit with the final design for the machine. First, the gap between electrodes are too large which is hard to fix since it will requires changing the mechanical part that will cost time and effort. Second, this balanced type is hard to attach to the slider of the machine that move up and down automatically, it is better used by hand. However, to fulfill final design, we decided to take a new design for the Auto Balance Welding Hand.

The new design should fit well with the slider, and it has a suitable connector for the copper wire which connect from the electrode set to the transformer. Below figures will illustrate the 3D design and the balance welding hand set that we acquired.

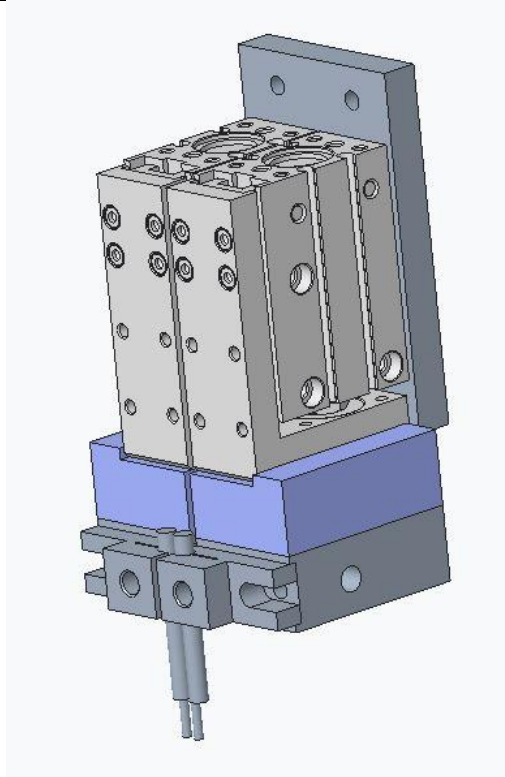


Figure 28: Auto balanced welding hand.



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This welding hand has a small air valve system built on the side, and on top of each piston that holds the electrodes that is numbered with 1 and 2 in Figure 29.

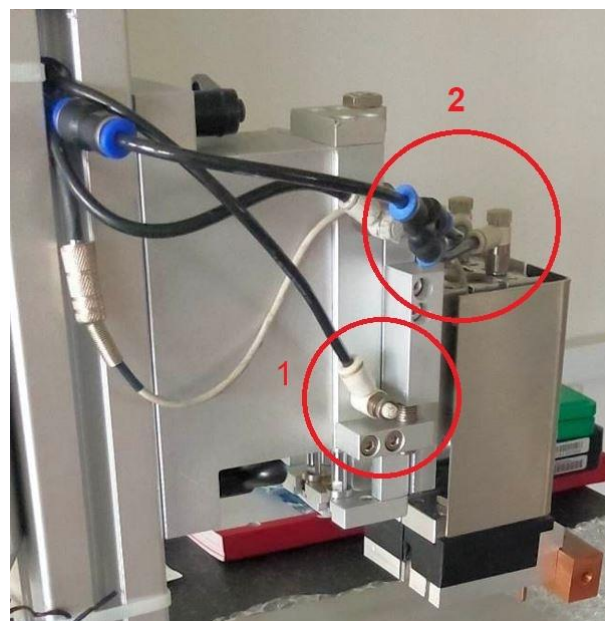


Figure 29: Air pipe design for the piston of the machine.

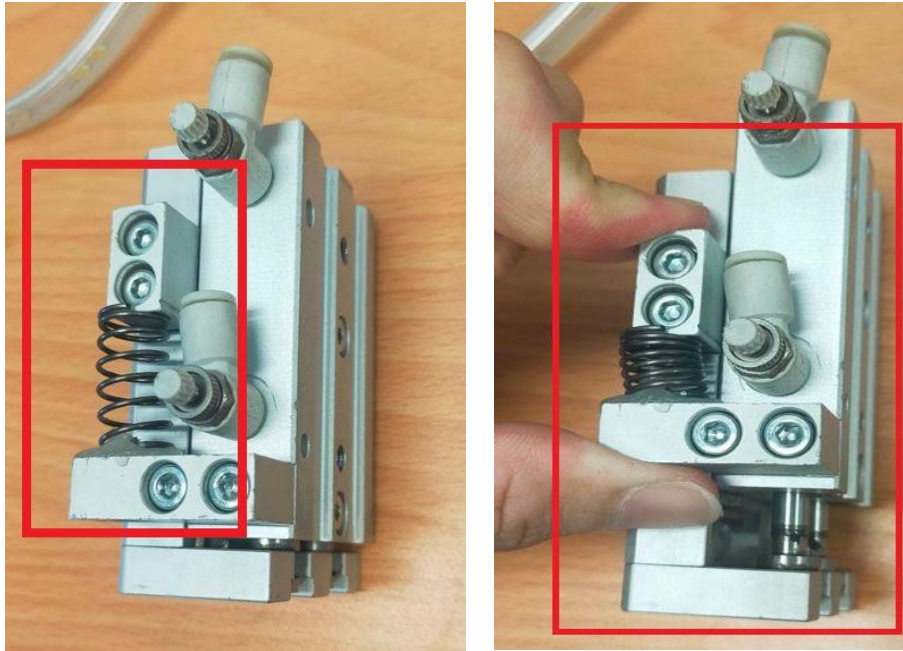
The role for each air valve will be describe as below table:

Table 2: Description of air valve functions.

Air valve number	Description
1	<p>This valve will control the speed which the piston moving up and down. By releasing the vale, more air will be release and piston will move faster. However, the moving speed should not be too fast or it will damage the machine's piston.</p> <p>To mitigate the damage that is created when the piston is moved to the top, a rubber tube is placed on top of the piston. When the whole piston reach to the top, that rubber tube will hold between the piston and the base on top.</p>
2	<p>This 2 valves will act as the guiding way for the air to go inside the pistons which help them move easily.</p>

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The idea of using air pressure to control the movement of pistons instead of logic programming for the machine brings a lot of advantages. When choosing the welding hand for a spot welding machine, other designs usually use the welding hand that had the spring mechanism. This mechanism is widely used since the spring helps retracts the electrodes faster and stronger. The spring mechanism is also a cheap part that can be replaced. The quality of the spring for a long time of usage will be decreased, for instance, its stiffness will reduce overtime and after all, will affect the quality of the final product. Another reason for replacing the welding hand that uses spring mechanism is that this is a very small component that is fixed inside of the so it will be very hard to replace; the only solution when this part gets problem is usually buy a new welding hand, which is a not the most optimize solutions, since it would cost much over the long run. Another problem is that spring is easily to bend out of place under high load without protection.



*Figure 30: Spring defect*



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To encounter this problem, our machine will use a set of piston system that operate by air pressure. The advantages of air pressure piston are enormous:

- Easy for installation.
- Can be controlled easily.
- Low maintenance cost.
- Does not require much mechanical parts.
- The air pipes can be separated make it easier for transportation.
- Air pressure can be adjusted to very small number by an air valve which means, the electrodes can exert different press force on the battery cell, helps the welding joint stick stronger to the work pieces.

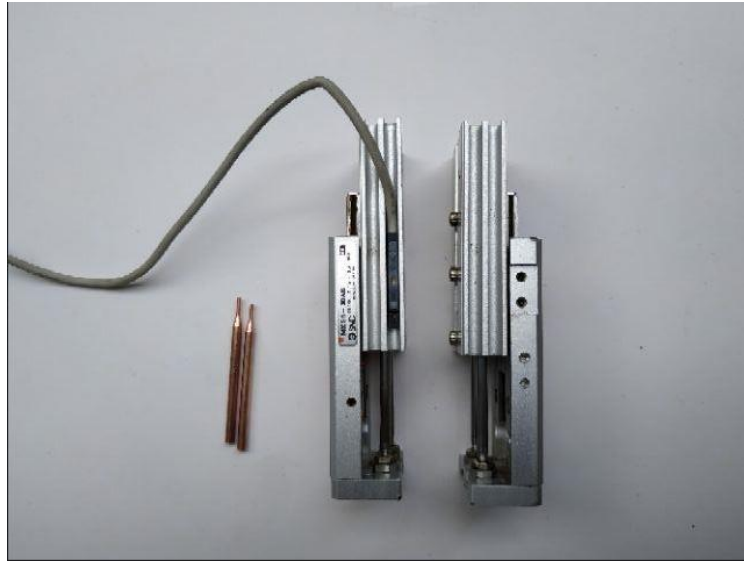


Figure 31: Auto balance piston welding hand.

This system will be applied to help the welding hand to move automatically and also, control the pressure which the piston will exert upon the welding specimens.

As the pressure that exerted on the welding nuggets is important because it will decide the quality of the final product, it is necessary to have a clock for observing the change in pressure and adjust with high precision. To determine how much air pressure should be put in used when the electrodes contact with the battery we used the following formula:

$$\mathbf{F = P \times d}$$

- **F:** Pressure force
- **P:** Cylinder pressure
- **d:** Bore diameter of the cylinder

## 2.2.5 Covers

Covers are simple part but its role is important as protecting the transmitter is crucial. Without it, dirt and sometimes, the smoke from the welding process may cause the transmitter to malfunctioned.

The material used to make the covers is also aluminum with 1mm thick. Holes which are made to fit the M4 hexagonal bolts sink is made so that it can be attached to the sensor.

These 2 pieces of covers can be taken from outside supplier and be manufactured followed by the needs of the consumer. However, we decided to make them from the aluminum plates that we already have so it would be faster and easier.



*Figure 32: Cover for transmitters*

## 2.2.6 Generator

The generator for the battery spot welding machine is usually made from the transformer of the microwave oven. Overall, the whole system requires

- Step-up transformer.
- Step-down transformer.
- A timer control board.
- A limit switch.
- A pair of copper wires to connect from the transformer to the electrodes.

A completed generator model will be shown as below figure



**Figure 33: Generator**

Parameters of the generator:

- Length: 350mm
- Width: 350mm
- Height: 190mm

Behind the pulse box are connectors gate which are used to connect the copper wires to anode and the other one will be connected to power source.





Figure 33: The behind of generator for battery spot welding machine

Deeper explanation for other parts of the generator will be illustrated in the next part of this project.

### 2.2.6.1 Transformer



There are 2 type of transformer, Step-up and Step-down transformer. Transformer consist of **Primary Winding (N1)** and **Secondary Winding (N2)**.

- For **Step-up transformer**, the function is to increase the input voltage from the **Primary Winding (N1)** and increase it on the output side, which is the **Secondary Winding (N2)**. We can understand that in this type of transformer, **N1** is less than **N2** ( $N1 < N2$ ). Beside increasing the voltage to make it suitable for the requirements of the users, this transformer also produce electricity over time to keep the whole system stay alive while turning on.
- **Step-down transformer** is opposite. It helps decreasing the input voltage to make the electricity load suitable for small parts such as control board or module. This transformer has the number of **Primary Winding (N1)** more than **Secondary Winding (N2)**  $N1 > N2$ .

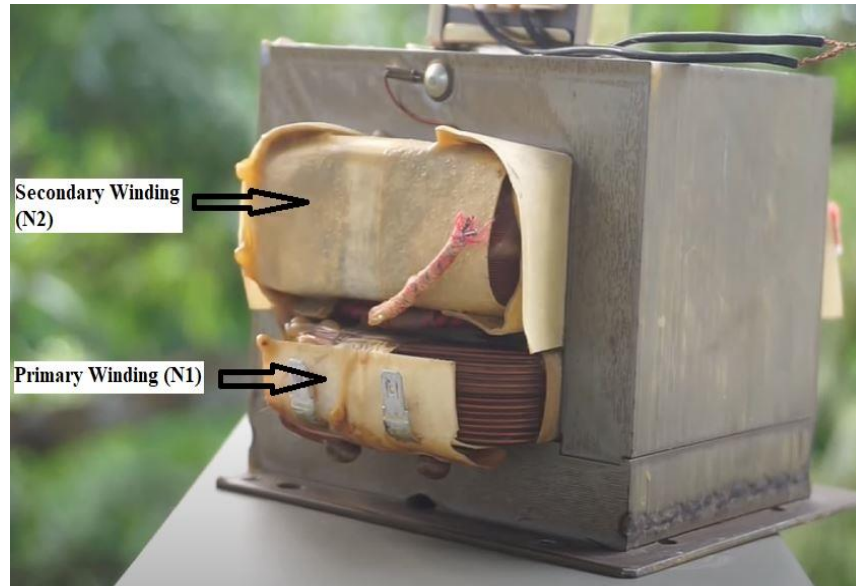


Figure 34: Step-up transformer

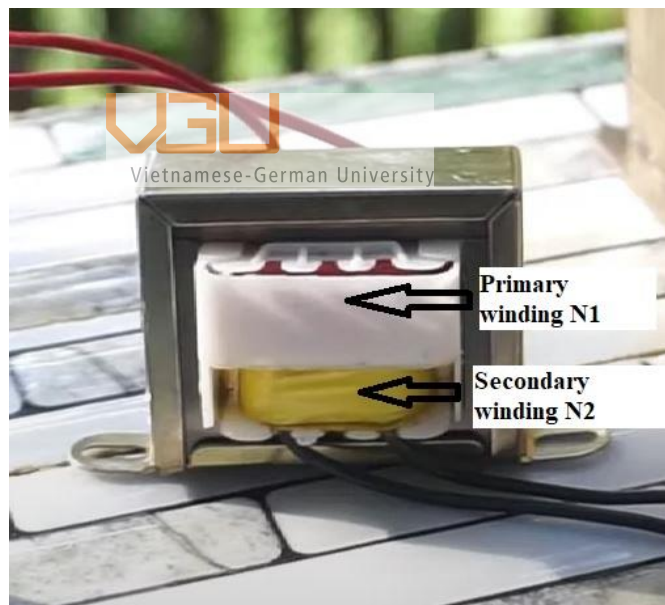


Figure 35: Step-down transformer

The differences between 2 transformers can also be recognized by the size. Normally, the size of Step-up transformer is usually bigger than Step-down transformer.

The main part of the transformer is how to make the winding that can replace the **Secondary winding (N2)** of the **Step-up transformer** since the original diameter of the copper wire is too small to link it into the electrodes.

- **Step-up transformer**

The most important part of battery spot welding machine is the transformer. This transformer can be taken from microwave. Since the Primary transformer of the microwave is not suitable for the main purpose of this project so it needed to be modified. The material which is used to make this is iron plates. To calculate what is the total number of thickness that a transformer should be, we need to know about these basic information:

- **Primary input voltage (U<sub>in</sub>):** Input voltage of transformer.
- **Secondary output voltage (U<sub>out</sub>):** Output voltage of transformer.
- **Wattage of the transformer (P):** Unit usually are KVA, Ampe (A) or KW.

First, we need to find out the area to which, it will suitable with the wattage of the sot welding machine. Electricity in Vietnam has the frequency of 50Hz; therefore, we can determine the area of the transformer through this formula:

$$P = (K \times \eta \times S^2)/14000 \quad (1)$$

**P:** Wattage of the transformer (VA).

**η:** Coefficient of performance.

**K:** Open flux coefficient.

**S:** Area of turns around the iron-core (mm<sup>2</sup>).

Table below will show the magnetic flux of silic steel and magnetic flux coefficient which is usually used to make the core of transformer:

Table 3: Fe properties

Material for the core	Open flux coefficient (K)	Coefficient of performance (η)

Thickness 0.35mm	0.93	0.84
Thickness 0.5mm	0.9	0.82

From formula (1), the area can be calculated as:

$$S^2 = (P \times 14000) / (K \times \eta)$$

In Vietnam, the Silic-Iron plate that used to make the transformer has the thick ness of 0.5 mm. Therefore,  $K = 0.9$  and  $\eta = 0.82$ . If we take the wattage of the machine is  $P = 240VA$ , the area should be:

$$S^2 = (P \times 14000) / (K \times \eta) = (240 \times 14000) / (0.9 \times 0.82) = 4,552,846 \text{ mm}^2 \Rightarrow S = 21.3 \text{ cm}^2.$$

Below picture will illustrate the total **width (a)** and the **thickness (b)** of the Iron core for the transformer. With the area  $S = 21.3 \text{ cm}^2$ . We can assume that  $a = 4\text{cm}$  and  $b = 5\text{cm}$  is suitable with the Wattage (P).

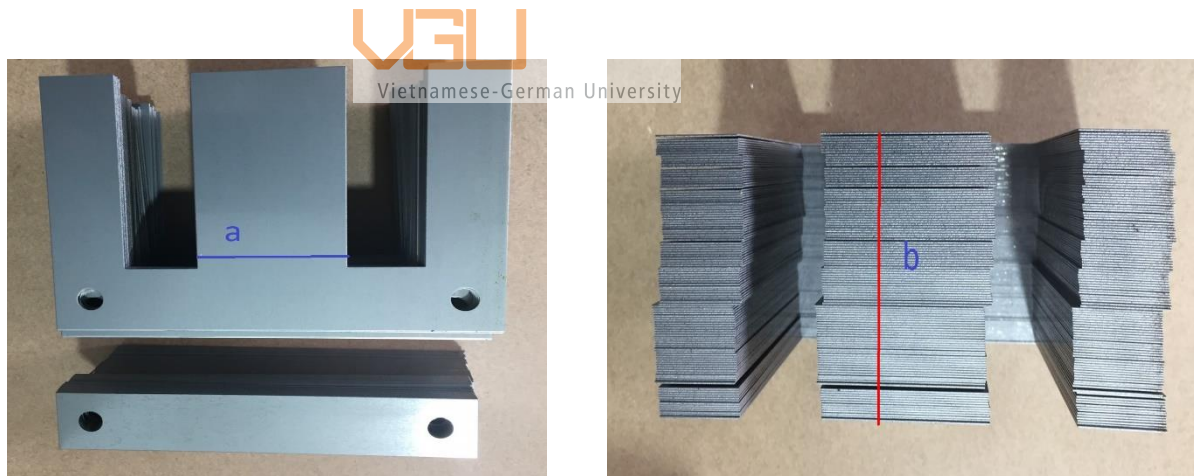


Figure 36: Total parameter indicator.

Normally, the core for the transformer are made from the combination of many Iron-Silic plates. These plates do not have a detailed design to match 100% with the area formula because the design of the Iron core for the transformer on the market has fixed parameters so we can choose the design with the parameter of  $a = 35 \text{ mm}$  and  $b = 70 \text{ mm}$ . Others core with the same parameters can be chosen as well.

It is also important to make an insulator frame. This frame will fix the Fe plates in places and help assemble parts together easier. This part is usually made from insulating plastic with good heat resisting or insulating paper.

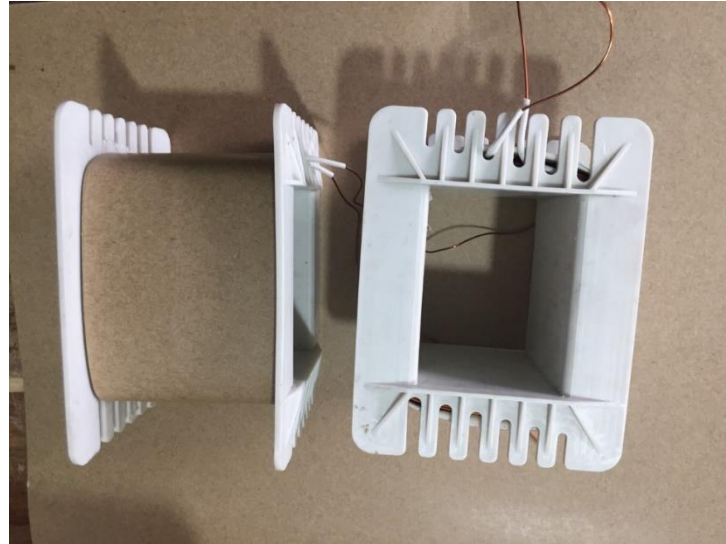


Figure 37: Insulator frame.



However, the size of the transformer that is used in this project is bigger than the one that is calculated in the above formulas, so it would give out different output. The changes for the calculation will be discussed further in the following parts of this project.

Next is the calculation for the number of turns for **Primary winding** and **Secondary winding** [6].

- **Primary winding (N1) and Secondary winding (N2) calculation:**

Iron core parameters (as shown in **Figure 37**):

$$a = 35\text{mm} = 3.5\text{cm}$$

$$b = 70\text{mm} = 7\text{cm}$$

$$\Rightarrow S = a \times b = 2450\text{mm}^2 = 24.5\text{cm}^2$$

**K:** open flux coefficient (can be understood as the gap between each Iron plates of the transformer). Standard of this component is **0.5mm**.

**$\eta$ :** Coefficient of performance.

**S:** Area of turns around the iron-core (mm<sup>2</sup>).

**F:** Magnetic permeability (varies from 35 to 50, depends on the condition of the Fe core. Usually be chosen as 35 for new Fe core).

**P:** Power of the Fe core.

**U<sub>1</sub>:** Primary voltage (V).

**U<sub>2</sub>:** Secondary voltage (V).

**I<sub>1</sub>:** Primary current (A).

**I<sub>2</sub>:** Secondary current (A).

**J:** Coefficient of current density (Varies from 3 A/mm<sup>2</sup> to 5 A/mm<sup>2</sup>).

**D:** Diameter of wire.

First we will determine the power of the Fe core:

$$P = (K \times \eta \times S^2) / 14000 = (0.9 \times 0.82 \times 2450^2) / 1400 = 4,429,845 / 1400 = 3164 \text{ (VA)}$$

$$\Rightarrow P = 3164 \text{ V.}$$



To find out how much turns it takes to produce 1 vol, we use the following formulas:

$$N/V = F/S \text{ (F can be 35, 40, 45 for different Fe conditions).}$$

**N/V** represent for the number of turns that will produce 1 voltage.

For this situation, the **S = 24.5 cm<sup>2</sup>**

And to find out the number of turns that will suit for the **Primary-winding (N1) and Secondary-winding (N2) of the Step-up transformer**, we use the following formula:

$$N = N/V \times U.$$

The voltage on the output of Primary-winding is 230V and Secondary-winding is 5V so we have **U<sub>1</sub>=230v** and **U<sub>2</sub> = 5V**

<b>F</b>	35	40	45
----------	----	----	----

<b>N/V</b>	0.7 turn/vol	0.8 turn/vol	0.9 turn/vol
<b>N<sub>1</sub></b>	161 turns	184 turns	207 turns
<b>N<sub>2</sub></b>	3.5 turns	4 turns	4.5 turns

After determine the number of turns for **Primary** and **Secondary winding**, we will find out the **bearing load** (which is the electrical capacity) of the wire to find out the final diameter of each winding.

#### **Primary winding parameters determination:**

$$P = U_1 \times I = 3164 = 230 \times I \Rightarrow I = P / U = 3164 / 230 = 13.7 \text{ (A)}$$

$$\text{Size of } N_1: A_{N1} = S \times J = 5.6 = S \times 5 \Rightarrow S = 13.7 / 5 = 2.74 \text{ mm}^2 \Rightarrow S = (D^2/4) \times 3.14$$

$$\Rightarrow D^2 = \frac{S \times 4}{3.14} = \frac{2.74 \times 4}{3.14} = 3.4 \Rightarrow D = 1.8 \text{ mm}$$

As the calculated diameter for the **Primary winding** can varies from the calculation for about 0.2 to 0.4 we decided to use the wire has the diameter of  $D = 1.4\text{mm}$ .

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After the calculation, the suitable diameter of the wire used for the **Primary winding**, next is the steps to find out the parameter suitable for the **Secondary winding**.

#### **Secondary winding parameters determination:**

As the number of turns for the **Secondary winding** varies from 3.5 to 4.5 turns. We decided to make the number of turns is 4  $\Rightarrow N_2 = 5 \text{ turns}$ .

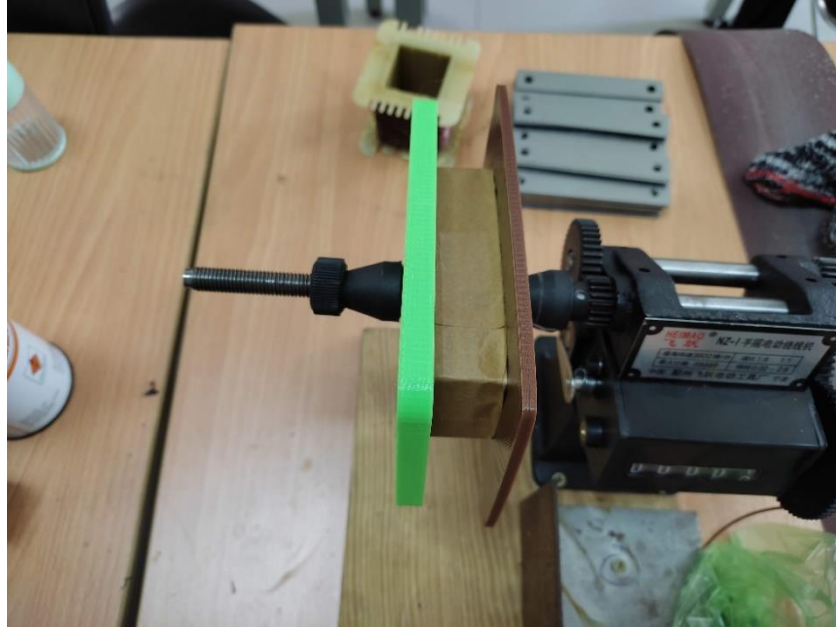
For **Secondary winding**, the material used is flatten copper with the diameter of 3x30mm with the thickness of 3mm. By bending this material to make the wiring, it will stay stronger and also has a better electric transmission.

In conclusion, the new **Primary winding** will use the copper wire with the parameter of  $D = 1.2\text{mm}$  and the number of turns can vary from **161 to 207 turns**. The new **Secondary winding** number of turns is **5 turns**

#### **Wiring for Primary winding and Secondary winding.**



The next steps are to wire up the **Primary and Secondary winding**. To accomplish this task, we used an auto wiring machine that was made from a hand-drill, since the material used was copper and it would be very hard to do it by hand.

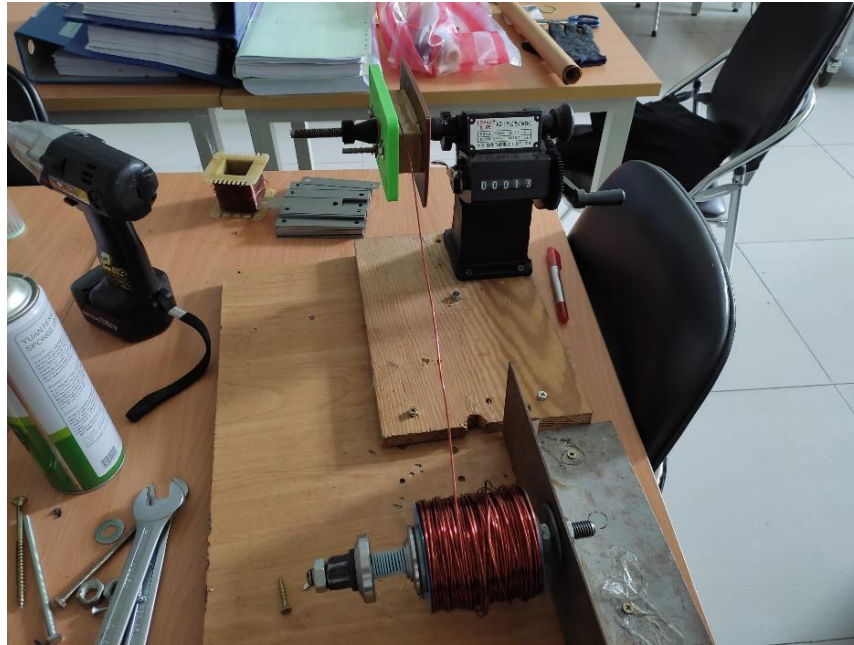


*Figure 38: Wiring machine*

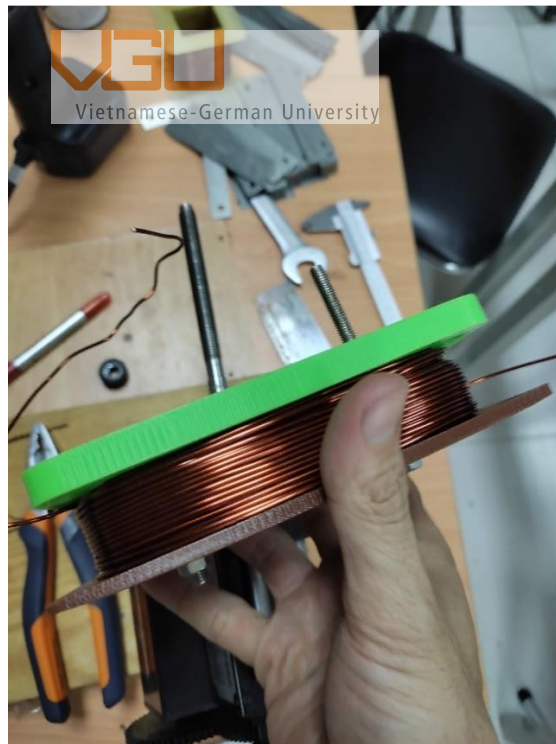
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The copper coil is then connected to the rectangle core and by spinning the drill, the copper wire will be turned around the shaped core and create the **Primary winding** of the transformer.





*Figure 39: Wiring process for the Primary winding.*



*Figure 40: Final result of the Primary winding.*

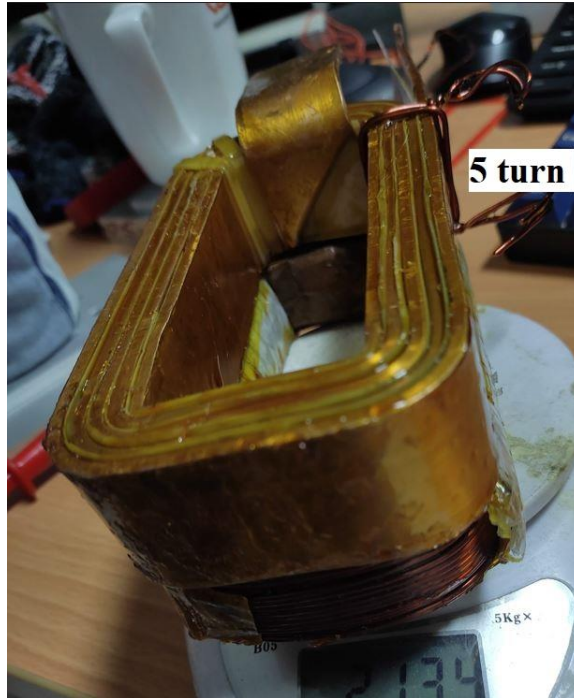
The **Secondary winding** will be modified to be suitable with the design of the machine. Because the final design will put the transformer inside the generator; therefore, the wire will be replaced with copper plate that will be flattened down to make it 4 turns around the iron core. With this design, final size of the transformer will be more compact and easy to fit in the generator.

To make the copper plate in shape with the Fe core, we use a clamping device to hold the plates as strong as possible. After being held like that, the plate will be form in shape and make it easier to fit in the generator box.



*Figure 41: Clamping device*

After shaping for the copper coil, the winding started to begin. As the copper plate is easy to bend by hand in to 4 turns.



*Figure 42: The secondary winding of the transformer.*

After wiring up, to deal with the small gap between the turn and also deal with the safety of the users. To encounter this, we use a compound called **Epoxy resin** to fill up the gap as well as to cover up the outside of the coil, since this compound is non-conductive, it is possible to be an insulator to ensure the safety for users. Other benefits of this compound can be named as:

- **Good strength:** When contact with other substances, the **Epoxy** usually illustrate better strength, the reason is because is **Epoxy** has an adhesive bond which maintains their resilience for the long time.
- **Highly versatile:** Because of the versatility, it is easy for this compound to bound to multiple materials.
- **Durable:** The **Epoxy resin** provides a large amount of stability, making it reliable and durable. As a result, it is quite good resistant to other chemicals and weather.
- **Easy to apply:** As the basic form of this compound is liquid, it is easy to apply to mostly every surfaces. This feature is important to this project because the **Primary and Secondary winding** are copper wire that is wind up.

- **Thermosetting:** The **Epoxy** compound is not melt easily under the normal working condition of the battery spot welding, making it the suitable one for covering up the **Primary and Secondary winding**. This compound also gets super hard once setting up is done, which makes a good cover for the windings.
- **No shrinkage:** The probability that the **Epoxy** shrinks is less than 1%. This mean it does not get weak or shrink once it is settle appropriately and it will stay in its desires form for the long term.

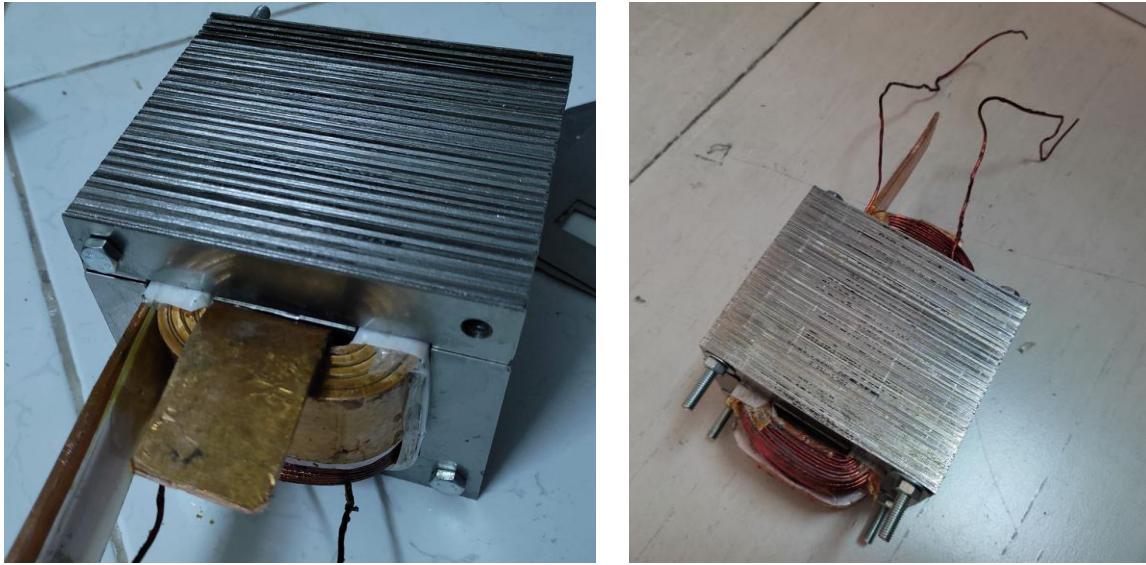


*Figure 43: Covering the Primary and Secondary winding in the Epoxy compound.*

After calculating and preparing all the parts that are required, final step is to assembly all the parts together. By connecting all the **Fe plate** for the **iron core**, the **Primary winding and Secondary winding** together, we successfully made a transformer for our machine.

Below are images of the completed transformer made for the machine:





*Figure 44: Transformer of the machine.*

### **Connection from the transformer to the electrodes.**

The new copper cable is made from the combination of original copper wires and using a heat shrink tube as a wrapper to create a copper tube with diameter varies from 5mm to 8mm. This tube cover made from Polyolefin, the temperature at which this material shrink is 90°C to 125°C, once it wrapped up, it will create a strong attached tube and also flexible enough to be winded around the iron core of the transformer.



*Figure 45: Copper cable used for Secondary winding*



*Figure 46: Heat shrink tube*



*Figure 47: New copper cable for Step-up transformer.*

To connect from the copper cable to the electrodes of the machine, we use a copper lug to connect the wire to a bolt that was made on the side of the auto balance hand.

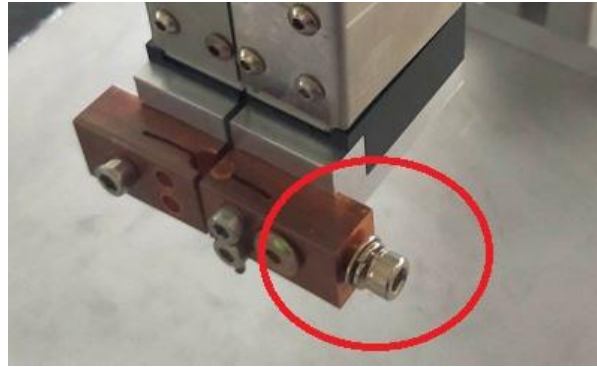


Figure 48: Attaching tool for the Copper Lug.

This lug helps to increase the conductivity of the copper cable when they are connected to other devices. They are made from aluminum (99.95%). With this property, copper lug has a good conductivity, the copper plating increase the exposure, prevent corrosion and protect user from electricity discharge. Table below will show the design and parameters of the lugs, which suitable for different installation.

Table 4: Parameters of Copper Lug



Lug types	Dimensions(mm)			
	A	B	C	D
10A	9,1	5	19	0,7
20A	10,8	6	22,8	0,7
30A	10,9	6	24	0,7
40A	11,9	6	25,5	0,7
50A	12,4	6	27,6	0,9
60A	13,9	8	29,6	0,9
80A	14,3	8	32,4	0,9
100A	16,8	8	37,5	0,9
150A	17,3	10	39,5	1
200A	18,8	10	41,7	1

### 2.2.6.2 Timer control boards.

Circuit board that is used for the generator holds the responsible for controlling time and adjusting the electric current in order to give out the products that meet the requirement of the

operator. The timer which is used in this project is BTA-100 circuit board. This type of circuit board can take the electric current from 40A to 100A. Basic information of this type of control board are:

- Backup battery electric source: 9 – 12V AC.
- Electric source: 9 -12 AC.
- Maximum load current: 40A/100A.
- Left potentiometer (for time adjusting): following the user.
- Right potentiometer (for adjusting electric current): 50 to 99% depends on the thickness of welding nuggets.
- Parameter: 77x50mm

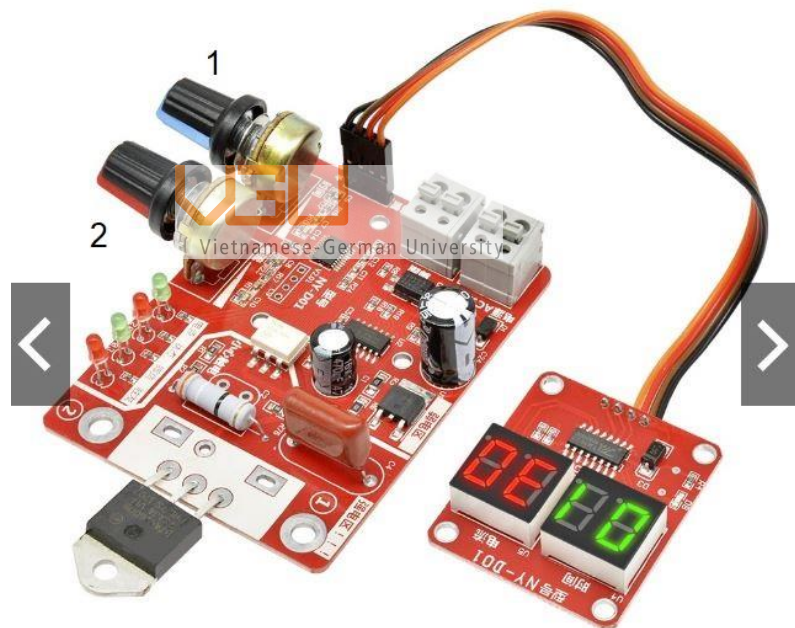


Figure 49: Timer control board BTA100

To successfully installed this control board, provider gave us a wiring diagram which showed how to board should be wired and how to connect the board into the system. Figure 35 and



Figure 36 will show the wiring diagram and how to install the BTA control board into the whole system respectively.

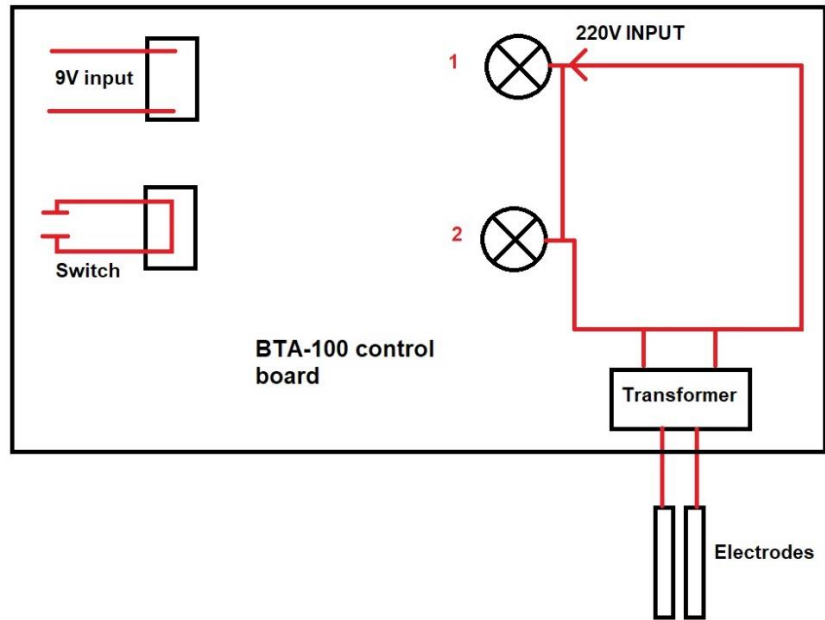


Figure 50: Wiring diagram for BTA100



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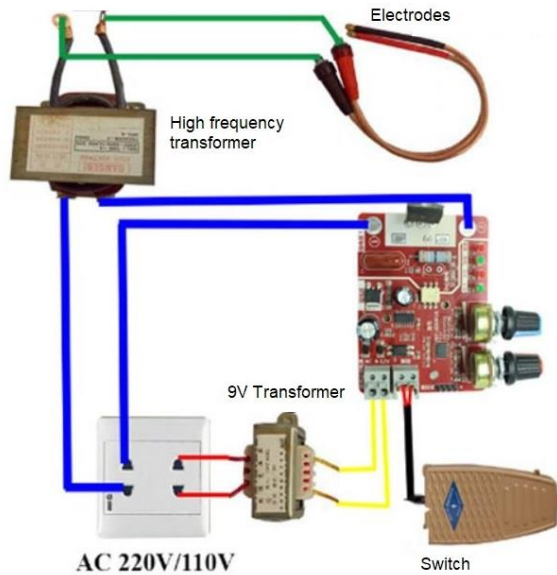


Figure 51: Installation diagram.

There are some notifications that needs to be noticed when using BTA-100 control board. The first one is the switch; there are two turn switch on the board that is marked with number 1 and 2 that is shown in Figure 34. The purpose of switch number 1 is to adjust the time and number 2 is for the current adjustment. For instance, if the nickel used to connect the battery cells is thick, users should set the time to be longer and increase the electricity current.

After installing the timer control board it is necessary to check if the timer is working or not. By connect the wire into a lightbulb and press the switch. If the lightbulb glows for a short time as set up in the control board, then it is wired right.

### 2.2.6.3 Switch

This switch is connected with the timer control board BTA100 and helps the generator transfer electricity into the electrodes.

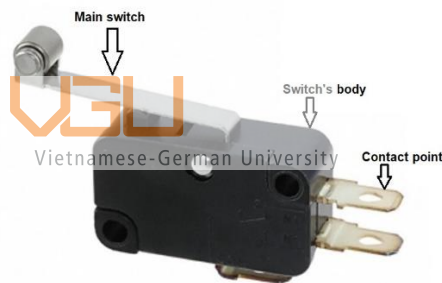


Figure 52: Limit switch used for the generator.

This limit switch is our first choice since the original design of the machine was simple and did not required much wiring, additional modules and an air pressure system which will help electrodes move up and down automatically. However, with some improvements which was suggested from my second supervisor, it is necessary to change from this switch to a different type. A button switch will be more suitable since it is easier to be activated.

### 2.2.7 Control board

Control board is the place for additional tools such as: relay timer control, on/off switch, activate button and an air valve that helps control the force of piston in the welding hand. Basic parameters for this control board will be shown as below:

- Length: 150mm
- Width: 120mm
- Thickness: 5mm

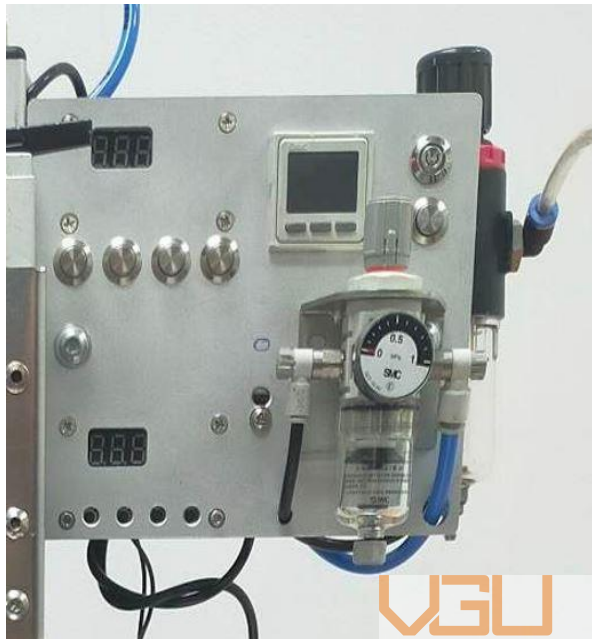


Figure 53: Control board's front view

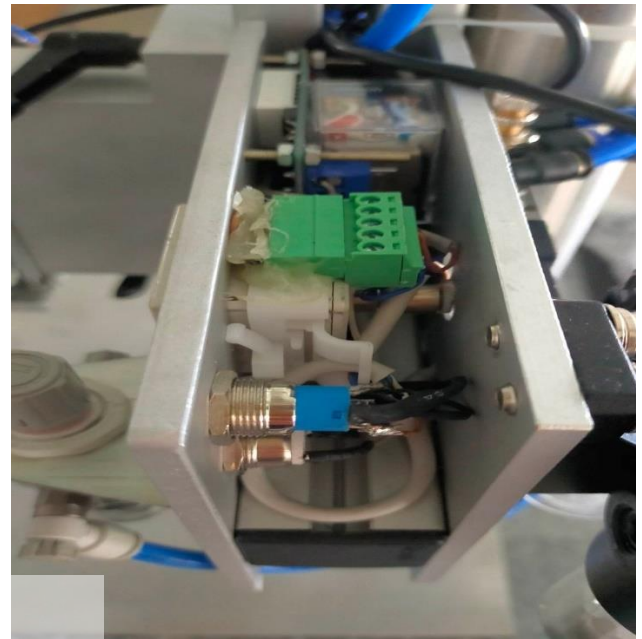


Figure 54: Control board's side view.

The control board for the machine should also be able to hold the on/off switch, additional modules of the machines, the wires which connects the control board and modules together, and the pipe line which will help the pistons that holds electrodes move automatically. Due to the massive amount of small tools that will be held at the behind of the machine, we decided to make 2 plates from aluminum. The front plate will hold the parts such as: modules, switch and an air pressure valve. The plate at the back helps to hold an air pressure valve and the connector gate of the module and the timer control board BTA100.

## 2.2.8 Conclusion

With the designing that is accessible and easy to be manufactured, our battery spot welding machine can be made from parts that are found at home. Making a machine from parts that is not connected to each other from the beginning will come some disadvantages such as: no detailed

guidelines, difficulties while manufacturing parts to make them suitable to be attached together, some parts may not be sold in local stores. Last but not least, some parts such as the Main Base or Control Board needs holes to attach small details onto it, so it requires a set of particular skill to use the drill and the milling machine to manufacture. However, because most of the mechanical parts of the machine are self-supply; therefore, the price of the machine is reasonable. During the manufacturing process, there will be fault details, these errors are usually created when the drilling bits tended to cut into the edges of the work pieces. However, they are minor problems and the machine can still be functioned while fulfilling these requirements:

- Low maintenance cost.
- Low manufacturing cost.
- Easy for installation and transportation.



*Figure 55: Overview of Battery Spot Welding Machine.*

Aside having the final product, the machine still has room for different improvements. Therefore, further work is in progress. The next topic of this project is to program for the machine, which will be discussed deeper in Chapter 3.



## **Chapter 3: Time relay module installation.**

For this project, the programming part required a deep understanding about the Time Relay Module and how it works. It includes the function of the control module, different modes of the module, how to set up the module to different use intentions and how to wire the Timer Relay Module so it can control the time interval that electric current will go through the electrodes. These modules will be attained from supplier and we will learn about different functions of them.

### **3.1 Introduction**

Another important part for the machine is the time relay module. For our machine, it is determined that 2 relay module will be used. One is to give the signal to the BTA control board inside the generator that responsible for the welding time of the machine. The second relay module will control the moving time of the pistons.

To control the electricity discharge time and piston moving, we decided to choose the JZ-801 module. This module has a reasonable price and most of the local electric store has it, so it would be easier to buy. One more reason is that this module has different modes that suitable for programming the time for the machine. These time modes will be discussed more in the following part of this project.

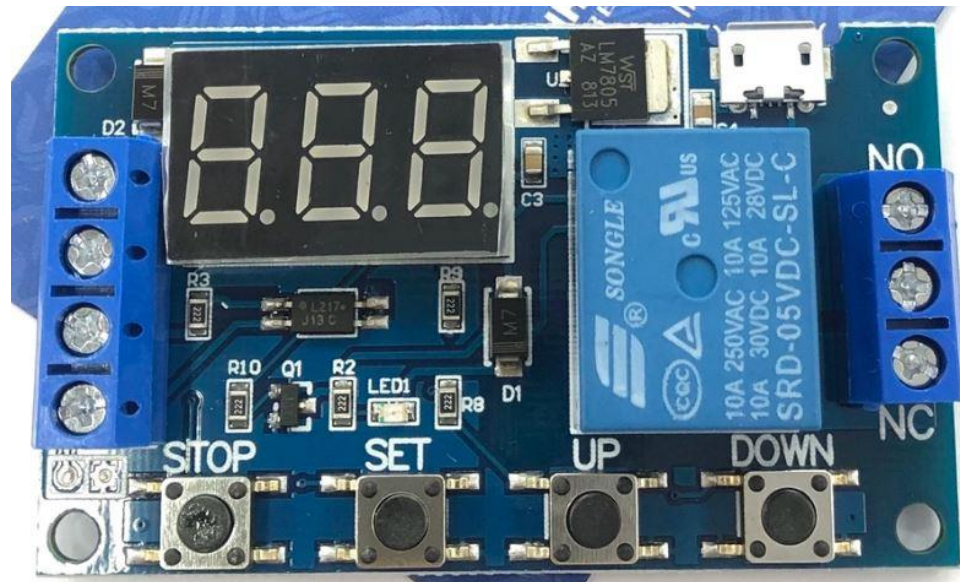


Figure 56: Time relay module JZ-801

This is a 1 Channel Delay Power Relay module and the timing cycle on this module is adjustable. This module can run on 6 to 30V and also can be operated by a 5V power supply through a micro USB. The output capability depends on the relay which is rated to control the load up to DC 30V 10A or AC250V 10A.

The Relay Timer Module is used for switching the connected load. The module has the ability to set up time till which the relay should be opened condition and when the relay should be closed. The time period that can be set in this module varies from 0.1 second to 99.9 minutes during open or close time. This module can be used easily with 4 function buttons:

**SET:** as introduced, there are different using modes that was programmed in this Relay Module. The **SET** button will determine which one of these modes will be used. At first, the LED screen shows 00.0, by holding the **SET** button, user can choose which modes to be used.

**UP AND DOWN:** these two buttons are used for showing other options that was programmed in the module. By simply pressing them, the LED screen will show different modes that user can choose. Also, we can adjust the time (minutes and seconds) using up and down.

**STOP:** through this switch, the module can be turn off or turn on again. By pressing this switch once, the LED screen will display **OFF** and after this, the Relay Module will not work, the time



on the screen may go; however, the relay will not be switched. Press the **STOP** button again will re-activate the module, the screen will show **ON** and the module will be ready to work again.

The **STOP** switch has another function that is put the module into sleep mode. By press and hold this button, the status of the module can be shifted into the status of C-P and O-d.

1. C-P: When the module is not in used for about 5 minutes, the display will be turned off automatically and the program will keep working.
2. O-d normal mod: Display of digital tube always on.

However, the sleeping mode is not necessary for this project since the workload of the machine is not excessive, so the sleep mode can be put aside.

Another important of the **STOP** switch is **Selecting the time range**. Based on different type of set up, the time can vary differently:

XXX - The decimal points set as unit digit and the timing range is 1 second to 999 seconds.

XX.X - The decimal points set as ten digits and the timing range is 0.1 to 999 seconds.

X.X.X - All the decimal points are lighted up and the timing range is 1 minute to 999 minutes.



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### 3.2 Operate modes

The relay timer comes in with different functions that will be discussed in the following part. But first there are several terms that needed to be noticed:

- **OP:** The time that the relay will be ON (normally open state)
- **CL:** The time that the relay will be OFF (normally closed state)
- **LOP:** The number of times the **OP** and **CL** will be running (repeat from 1 to 999 times)

Modes which was programed in the module includes:

- **P1.1:** This mode has an option for setting the time in which the relay module will be ON (OP) and as the time is finished, it will switch back to OFF (CL). To make the timer run again, simply press the trigger button again.
- **P1.2:** This mode has the same **OP** mode same as **P1.1**. But as soon as the module is trigger again while the **OP** time is running, the operation will restart



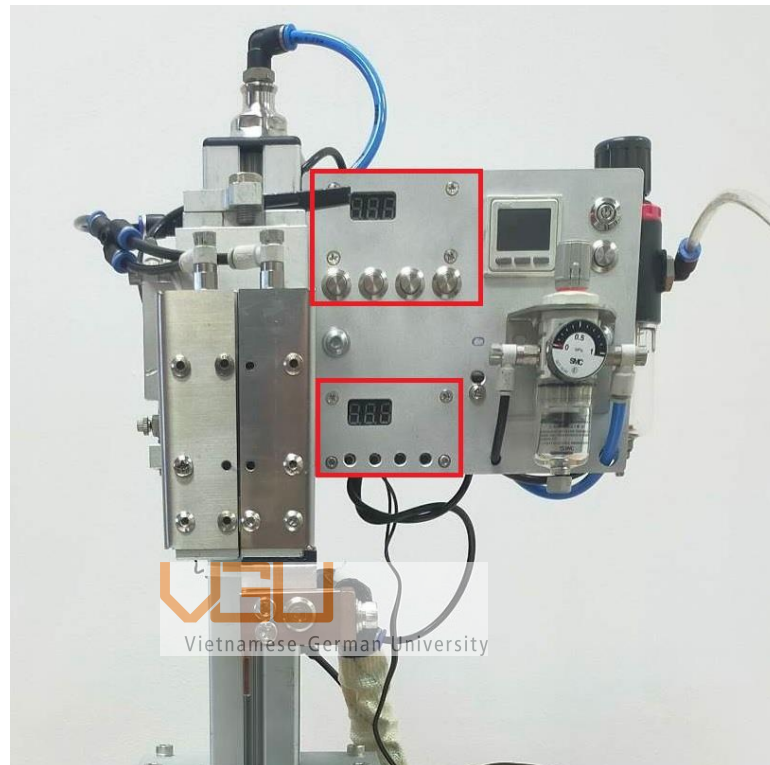
- **P1.3:** The **OP** mode is same as **P1.1** and **P1.2**. However, when the module is triggered again while the **OP** time is running, the module's clock will be stopped.
- **P1.4:** On this mode, the module only work when it got power to start. In simple terms, when the module is powered, the **P1.4** mode will start to work. The trigger button has no effect during the operation.
- **P2.1:** This function allows users to set up the time in which the relay will be ON (**OP** mode) and OFF (**CL** mode). When the module is powered, **CL** mode will run first and then **OP**. The trigger switch will not affect the running time.
- **P2.2:** This mode has the same function as **P2.1**. The difference is that if the module is triggered again while the **OP** or **CL** is running, the operation will be restarted.
- **P2.3:** It has **OP** and **CL** mode same with **P2.1** and **P1.2**. When the module is activated, **P1.3** operation start running. If the module is triggered while the **OP** or **CL** is running, the clock on module will be stopped and it will reset when triggered again.
- **P3.1:** In this mode, beside **OP** and **CL**, **LOP mode** will also put into use. When the module is triggered, the **OP** will run first and followed up by **CL**. If it gets triggered again while the time is running, module's timer will be stopped.
- **P3.2:** This mode is similar to **P1.4**. And as the module is started, this mode will start working and the trigger switch button will have no effect during the operation.
- **P4:** This function is similar with **P1.2**. The difference is that **P.4** mode has a single hold function, means that when the modules is triggered again, the **OP** time will be on hold and when the triggering stops, the **OP** time begin from starting point.

### 3.3 Installation for time relay module

For this machine, 2 timer relay modules JZ-801 will be installed in the machine. One is to control the working time of the BTA-100 timber board inside the generator. Its mission is to determine after which period of time will the BTA timer control board in the generator will let the electrodes release the electricity in to work pieces.

The other one is used to control traveling time of the welding piston. The travelling time can be defined as the time interval when the piston started to move down from the idle-above position to the idle-below position and back to idle-above.

These 2 modules will be placed at the back of the control board as shown by following figure:



*Figure 57: Position of time relay module.*

## Chapter 4: Air pressure applying, test running and final product.

After assembly the mechanical parts and design the air pipe for the machine, an air pressure support is put into use to help the machine run and produce its product.

This chapter will be divided into 2 parts. Since the air pressure helps the machine to operate, the installation of the air pressure and test running will be illustrated in part one. The second part of this chapter will show the final product of the machine.

### 4.1 Air pressure and running test for machine

The air compressor is connected to the machine to control the movement of the auto balanced welding hand. The pressure clock on the machine is to measure the amount of air inside the machine, it helps user to keep the air pressure of the air compressor stay at constant. If not, it may affect the force when the electrodes contact with the work pieces. However, this machine has a mechanic to always keep the air pressure inside the tank stay at constant pressure.



Figure 58: Air compressor



Figure 59: Air valve

After preparing the air compressor, we connect the air pipe to a tank that will be attached behind the machine. This tank is a storage that contains air and helps to adjust the pressure that affects the moving speed of the welding hand. The tank also has a pressure clock so users can decide when the pressure is too low and needs to be fixed at the right time.



Figure 60: Air tank of the machine

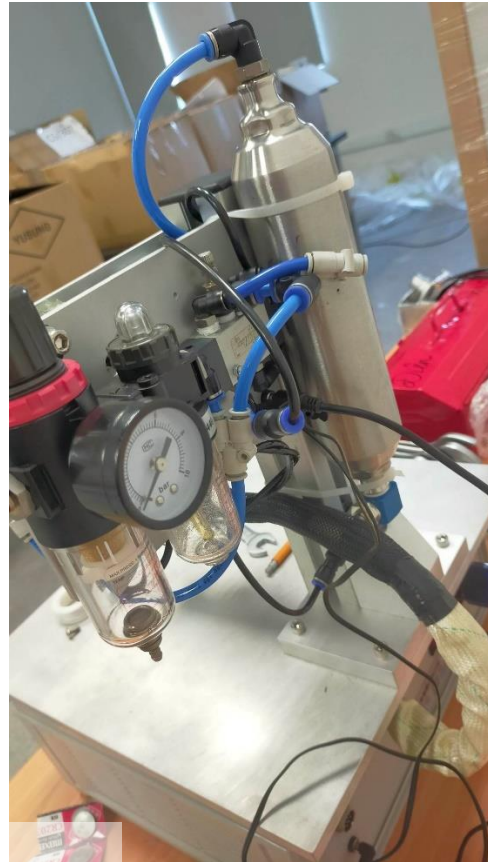


Figure 61: Air pipe system of the machine

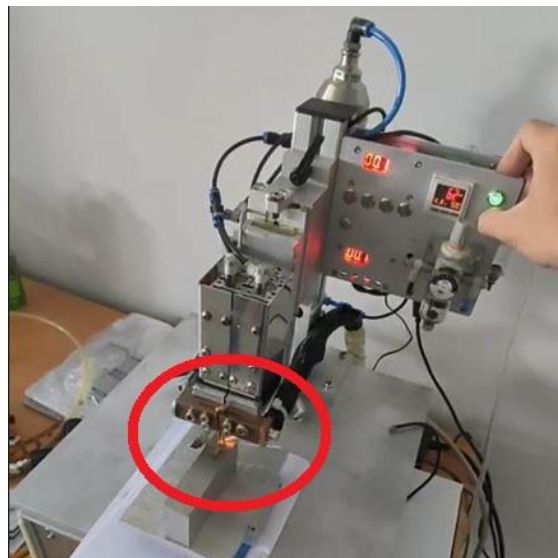


Figure 62: Spark when welding

To connect from the air compressor to air tank, we will use the type of pipe that has diameter of 8mm and from the storage to the electrodes, we use the air pipe with diameter of 4mm.

The running test of the machine does not require much space since the mechanical design is compact. This running will focus mainly on the startup time, cycle time, welding spark and final product of the machine.

- The startup time of the machine is quick since the control board and timer relay modules do not take much time to start. However, it takes roughly 2 minutes for the air compressor to fill up and after that, make adjustments of the air pressure.
- Since the spot welding for battery only about 0.01 to 0.63 seconds, it takes roughly 2 seconds for the welding hand to move down and up back to idle position. The quantity of the products is determined by users since it is operated by hand.
- Battery spot welding does not frequently produce much sparks due to the size of the electrodes and the specimens are small. Other factors such as pressure force and welding current also affect the amount of sparks that produce while welding. Overall, the sparks during the process of battery spot welding is not much; however, operator should wear goggles while using machine.
- By testing with the Nickel tabs that will be used to attached the batteries together, we will decide which are the factors that needed to be adjusted in order to make the welding nuggets stronger.

## **4.2 Result and discussion.**



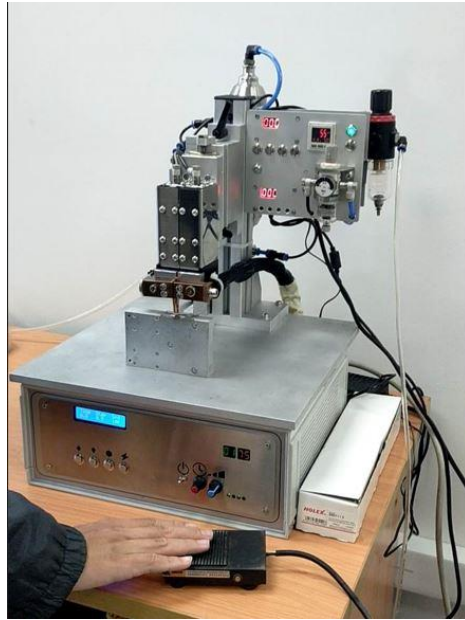


Figure 63: Machine before activated

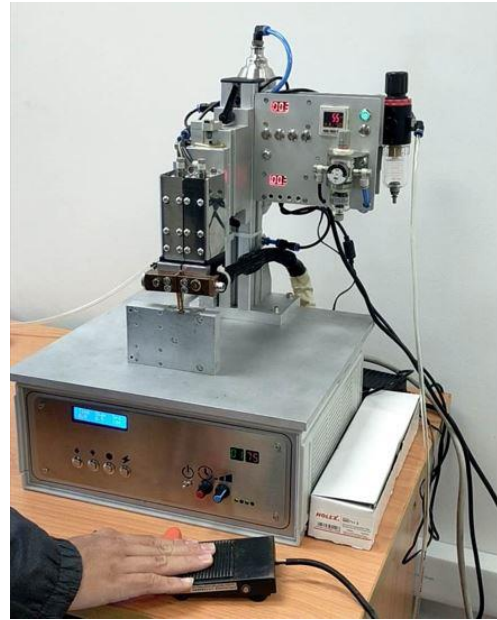


Figure 64: Machine during working



Figure 65: Machine when working cycle over.

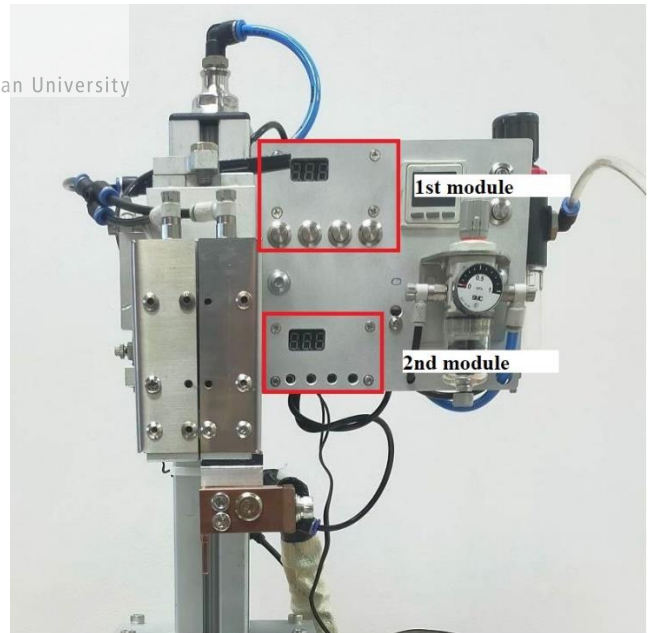


Figure 66: Timer relay modules position

Table 5: LED's screen timer

<b>Before activated</b>	The machine stays at idle position. At this point, the time relay module for the BTA and the module to control the travel time of the electrodes stays at 0.0 seconds.
<b>During work</b>	The working cycle of the machine is roughly 1 second, which will be illustrated by the second relay module. During this 1 second, the second relay module that responsible for starting up the BTA-100 control board will run and after 0.3 second, the relay module will give the signal for the BTA-100 to let the electricity runs through electrodes to the welding material.
<b>End of working cycle</b>	When the LED screen on the second module returns to 0.0 second, the electrodes also move back to the idle position.

The final result had shown a great strength of the welding nuggets on the nickel tabs which will be used to connect batteries together. While the machine was running, the air pressure used to control the speed of the electrodes sometimes get too low, this will affect the pressure force onto the work pieces as well as the retract time of the electrodes. However, we can overcome this issues by adjusting the air valve of the pressure clock.

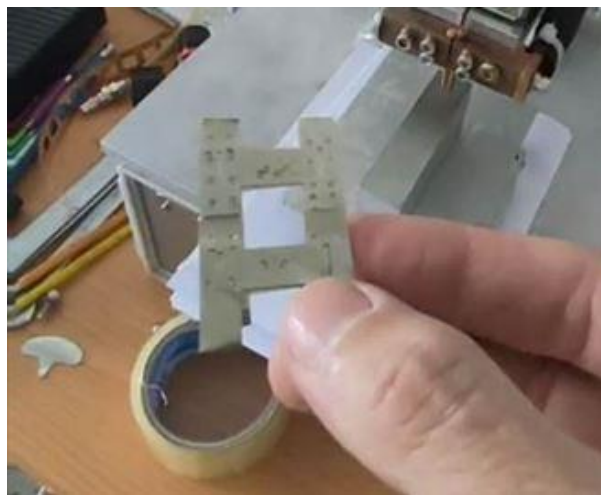


Figure 67: Welding nuggets of the nickel tabs

## Chapter 5: Conclusion and Improvements.

The main purpose of this project is to create a battery welding machine that has an understandable working mechanics and structure, the size of the machine should be suitable for small scale projects such as create battery cells for backup charger, battery series for electrical bicycle. As well as being fully operable, other requirements for the machine are:

- Reasonable cost for manufacturing.
- Easy for maintenance and transportation.
- Parts for making of the machine are easy to find

The machine is finally made and can be easily operated by one person. The requirements for the machine are also fulfilled. Further development and improvements for the air pipe system is required in order to reduce the down-time each time the air pressure in the machine get lower. The programming for the working cycle time and electricity transmit of the electrodes can be followed up by adjusting the BTA-100 control board and timer relay module. By running the machine and testing the ability to weld the metal sheet that will be used to attach the batteries together, it is safe to conclude that the machine has worked perfectly and create the welding nuggets that meets our requirements. The only issues that we have to deal recently was the copper wire connect from the generator to the electrodes has the cover that is easy to get torn out and reveal the copper inside. This problem can cause serious problem if users touch the copper part accidentally. However, this problem was solved by replacing the old cover with an insulate material.

Since the final product are made for electrical devices and it also relates to the safeness of users, the machine also needs the precision and accuracy in manufacturing metal parts. Therefore, it requires more calculation and programming with CNC machine to manufacture parts. However, the mechanical parts that used to make the machine are still in good condition after long time used; therefore, we should keep the manufacturing features to balance the size and the price for making this project.



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