# A Comparative Study on FeCrAl Alloy and NiCrSi Alloy Materials as Heating Element at Low Energy Oven

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# A Comparative Study on FeCrAl Alloy and NiCrSi Alloy Materials as Heating Element at Low Energy Oven

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## 1. Introduction

The need for human life at this time is increasingly complex, so that to help everyday life is needed practical, low cost and safe technology. This technological advancement is certainly not only aimed at the technology itself but more importantly for human welfare. One of the uses is in the industrial sector. In one industry, the process of drying fish. Then we need an oven that is safe, economical and environmentally friendly. In oven is used a heater to dry the fish, the heater has various type [1].

Oven is a device used to dry a wet material into dry material so that it can be stored for a long time. The drying process with the oven uses a medium that can hold the heat temperature constantly. The oven generally uses a heater [2][3].

As a source of heat generated by electric heating elements sourced from high-resistance wire or tape (resistance wire) usually the material used is Niklin wire which is rolled like a spiral shape and inserted in pipe as a insulator, then injected by electric current at both ends and coated with an electrical insulator that is able to continue heat well until it is safe to use . The shape and type of the electrical heating element varies according to the function of the installation place [4].

The conductive wire used for this research is FeCrAl alloy or Kanthal A-1 and NiCrSi alloy or Nichrome 80. FeCrAl wire contains 20% chromium, aluminum and ferum [5]. NiCrSi contains 80% nickel, 19.5% chromium and 1.45 silicon [6]. The reason for using FeCrAl and NiCrSi conductive wire is that both of these wires have low resistance, and produce high temperature.

The objective of this research is to obtain the best method for effective and efficient heating. Through an electrical analysis of the material, so that it is known that the type of wire is effective and efficient, to produce optimum heat. For further information which wire is suitable for heating element and low energy consumed.

## 2. Method

*A. Type of wire*

*A.1 FeCrAl Alloy/ Kanthal A-1 wire*. FeCrAl Alloy or Kanthal A-1 wire is composed of 20% chromium, 5.8% aluminum and iron. There are specifications of this wire: The density is 7.1 g/cm$^3$. Max operating temperature is 1400℃. Resistivity at 20℃ is 1,0 Ω mm$^2$/m and tensile strength is 680 N/mm$^2$

**Figure 1**. FeCrAl Alloy/Kanthal A-1 wire

*A.2 NiCrSi/Nichrome 80 wire*. NiCrSi or Nichrome 80 is composed of 80% nickel, 19.5% chromium and 1.45% silicon. There is specification of this wire: Density is 8.41 g/cm$^3$. Max operating temperature is: 1180℃. Resistivity at 250℃ is 1,02 Ω mm$^2$/m and tensile strength: 615 N/mm$^2$

**Figure 2**. NiCrSi Alloy/Kanthal A-1 Wire

*B. Sample*

In this research we use two different types of wire. Fe CrAl alloy and NiCrSi alloy with same wire and coil diameter

**Table 1**. Sample

| Type of wire | Wire Diameter (mm) | Coil Diameter (mm) |
|---|---|---|
| FeCrAl (Kanthal A-1) | 0.8 | 10 |
| NiCrSi (Nichrome 80) | 0.8 | 10 |

*C. Measurement*

*C.1 Resistance Measurement*. Using LCR meter to measure resistance

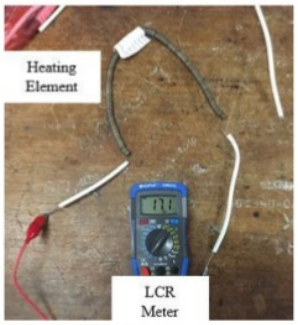


**Figure 3**. Resistance measurement

The phase probe (red) is connected to one end of the heating element and for the neutral probe (black) connected to the other end of heating element.

*C.2 Current Measurement*. Clamp meter was used to measure the curent that flow in the electric circuit as shown in Figure 4.

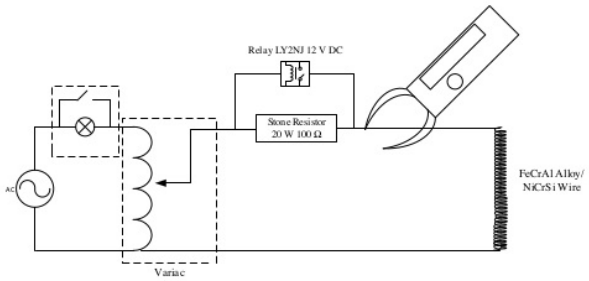


**Figure 4.** Current measurement circuit

From the AC Source 220 V connected with inrush then followed by variac to set the voltage (75 V) ). In variac there are phase and neutral section. From variac output phase connected with relay and resistor (as current limiter). The neutral connected to the wire. Then Current measurement is carried out on the phase section using clamp meter

*C.3 Power Measurement*. Power quality analyzer was used to measure electric power that it was consumed.

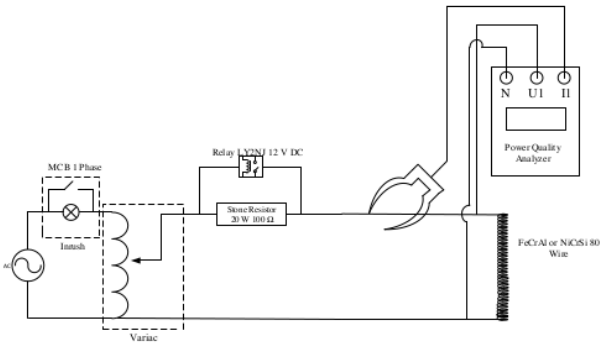


**Figure 5**. Power measurement circuit

Power measurement are carried out on the phase section for I1 probe, then U1 probe connected to phase section and N probe connected to neutral section. So we can get voltage, current and power parameters

*D. Temperature measurement*
Using thermocouple k- type connected with Arduino to measure the temperature inside low energy oven.

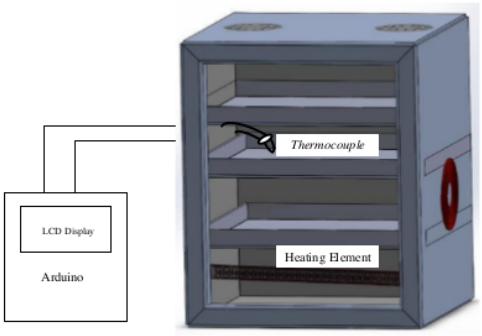


**Figure 6**. Temperature measurement at low energy oven

Arduino processed the temperature measurement from the thermocouple k-type then the measurement can be seen into LCD display

## 3. Result and Analysis

*A. FeCrAl wire Test*
In this research we use FeCrAl wire diameter 0.8 mm with 10 mm coil diameter. So we can see the result with table below

**Table 2**. FeCrAl alloy test wire diameter 0.8 mm with 10 mm coil diameter

| Resistance (Ω) | Input Voltage (V) | Current (A) | Power (W) | Time to reach 40 °C (minutes) | Energy to reach 40 °C (Wh) |
|---|---|---|---|---|---|
| 28 | 75 | 2.77 | 210 | 4.4 | 15.4 |

*B. NiCrSi wire Test*

In this research we use NiCrSi wire diameter 0.8 mm with 10 mm coil diameter. So we can see the result with table below

**Table 3**. NiCrSi alloy test wire diameter 0.8 mm with 10 mm coil diameter

| Resistance (Ω) | Input Voltage (V) | Current (A) | Power (W) | Time to reach 40 °C (minutes) | Energy to reach 40 °C (Wh) |
|---|---|---|---|---|---|
| 34.1 | 75 | 2.31 | 170 | 4.4 | 12.5 |

*C. Power consumtion between NiCrSi wire and FeCrAl wire*

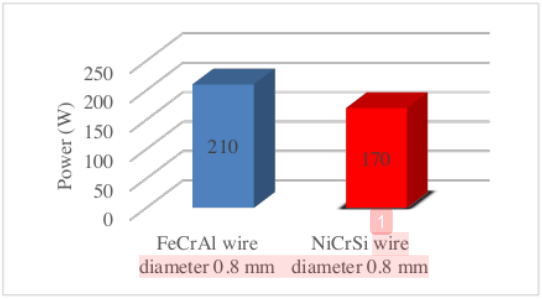


**Figure 7**. Power consumed between NiCrSi and FeCrAl

From Figure 7 we can see that FeCrAl wire consumed 210 W and NiCrSi consumed 170 W. FeCrAl consumed higher power than NiCrSi, because of FeCrAl wire has lower resistance than NiCrSi wire. In Ohm law, the current is inversely proportional to resistance. The smaller the resistance, the large current flows. Power is directly proportional to the current, if the current flows large, the power consumed is high. We conclude that NiCrSi wire consumed lower power than FeCrAl wire

D. Energy Consumed Between NiCrSi wire and FeCrAl Wire

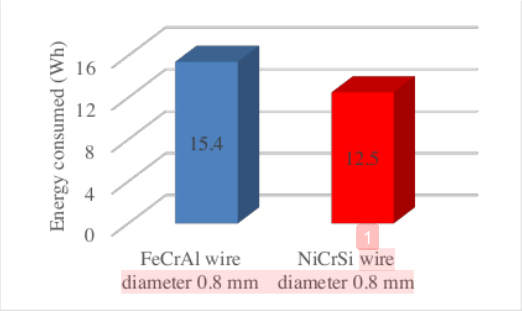


**Figure 8**. Energy consumed between NiCrSi and FeCrAl

From Figure 8 we can see that FeCrAl wire the energy consumed 15.4 Wh and took 4,4 minutes to reach 40℃ and NiCrSi wire the energy consumed 12.5 Wh and took 4,4 minutes to reach 40℃ . FeCrAl wire consumed higher energy than NiCrSi, because of FeCrAl wire has higher power than NiCrSi wire. Energy depends on power and time. Resistance affects the value of power, so if the resistance is low, then current flows is big, then currents affects power. Power affects energy consumtion. We conclude that NiCrSi wire consumed lower energy than FeCrAl wire.

## 4. Conclusion

In this paper, it can be concluded that NiCrSi wire is well used as a heating element at low energi oven, because it has low resistance, low power and energy consumption. The resistance value affects the current flow, the power consumed and the energy consumed

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