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JSMT

http://publisher.uthm.edu.my/ojs/index.php/jsmt

e-ISSN : 2821-2835

Journal of Sustainable and Manufacturing in Transportation

Development of Resistance Sintering Furnace for Heat Treatment of 22MnB5

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DOI: https://doi.org/10.30880/jsmt.2022.02.01.006
Received 24 November 2021; Accepted 17 August 2022; Available online 30 September 2022

Abstract: This paper presents the development of resistance heating furnace based on the direct electrical conduction method that can perform with lower energy. Based on the concept of resistance welding, resistance heating furnace was developed for heat treatment of 22MnB5 Boron steel with the aim to change the microstructure from pearlite to austenite phases before quenched into martensite phase. The main component for this machine consisted of transformer, copper electrodes, copper cable coil and wood frame structure. The design of the machine resembled resistance welding with upper and lower electrodes were assembled together mounted by the wood frame. The heating energy collected from the electrical current that flow through cooper cable that rolled through toroidal transformer. The result shows that the machine capable to heat the 22MnB5 Boron steel with maximum temperature of 721.2°C. However, the machine demonstrates overheat after 7 minutes due to the insulation burn of cooper cable. Further improvement of cooling system and copper insulation need to be addressed to prolong the heating operation.

Keywords: Resistance furnace, 22MnB5 steel, heat treatment

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1. Introduction

Furnace is a device to heat the product for heat treatment or sintering. The source of heating obtained are from electrical or gas energy. Furnace normally use for the heating or sintering the product for heat treatment or hardening processes [1-2]. Inside conventional furnace, the heating element were heated first by electric or gas energy before conducting heat inside inner chamber. To achieve the constant temperature, the specimen will be located inside the furnace until the warm air surround the specimen. The whole process took large energy and time to achieve stabilization, depended on the power of the furnace [3-4].

22MnB5 Boron steel is a special type of steel prepared in the form of rolling metal plate. This material categorized as Ultra High Strength Steel (UHSS) and applied as a car chassis due to the high strength and lightweight properties. 22MnB5 steel appeared to be very sensitive with the heat treatment where the microstructure tends to change from pearlite to austenite phases and directly into martensite when quenched with cooled water. Such microstructure transformation enables their strength increased from 500 MPa to 1500 Mpa [5-7].

In the practice of manufacturing process of 22MnB5 Boron steel, hot stamping method is applied to heat and form the materials. On the hot stamping process, the blank of 22MnB5 Boron steel is heated in roller heath furnaces with length of 30–40 m until its reached austenization temperature. The part then pressed inside the dies enclosure to form according to the required shape. On the same time the quenching process was performed to the stamped part by cooling system inside the dies. This resulting the microstructure of the stamped part to change into martensite phase. Such machineries system more suitable for mass production and require high investment costs, which limited their feasibility for small and medium industry [8-10].

To heat a single 22MnB5 Boron steel blank, alternative approaches such as resistance heating is proposed. In principle, resistance heating come from the concept of resistance welding where two electrodes with high electrical current where pressed together with metal plates placed between them. Heat that generated from the electrical resistance between these metal plates suppressing their melting temperature. As the electrodes continually pressed, the molten area between metal plates were bonded and solidly joined as the electrode's pressure removed [11-13].

In this study, a resistance heating furnace was developed based on the of similar concept of resistance welding. A 22MnB5 Boron steel plate was placed between two electrodes while the high electric conducted through the electrodes. As electrical current conducted through specimen, the heat will be generated inside specimen due to resistance inside its body. Higher heat will facilitate the heat treatment process to alter their microstructure and change their properties.

2. Methodology

Fig. 1 show the design concept and component involved to develop resistance heating. In general, the furnace consisted of electrodes, large radius of cooper cable and mounting frame. The concept of the machine resembled of Caliman et al. [11]. Fig. 2 shows the component that involve prior the assembly of the furnace. Operation of resistance heating started with the clamp holder of electrode is place at the top of the machine. For the generation of current and heat, this machine used toroidal transformer as the power system. The transformer is placed inside of the housing to make sure the transformer is well protected. The transformer will generate high amount of current by coil the transformer using thick cable wire. This machine also equipped with the cooling system which is the cooling fan was installed in front of the transformer to avoid overheat reaction from the high temperature.

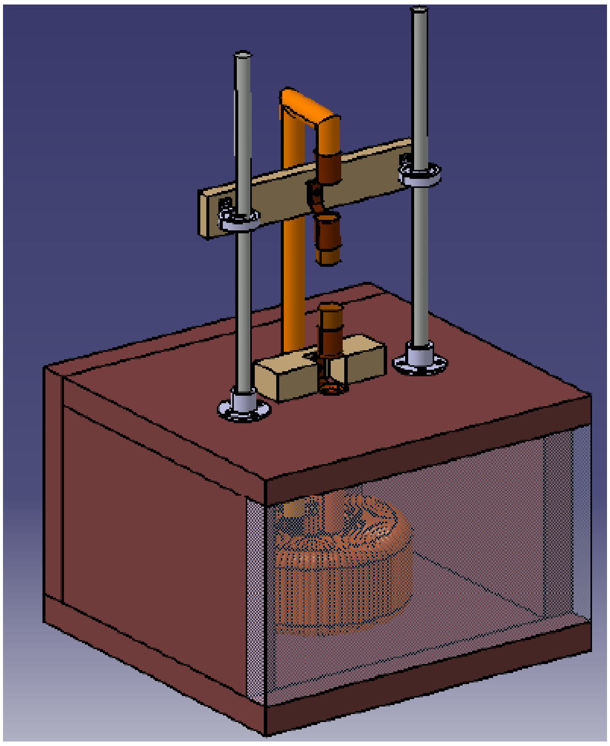
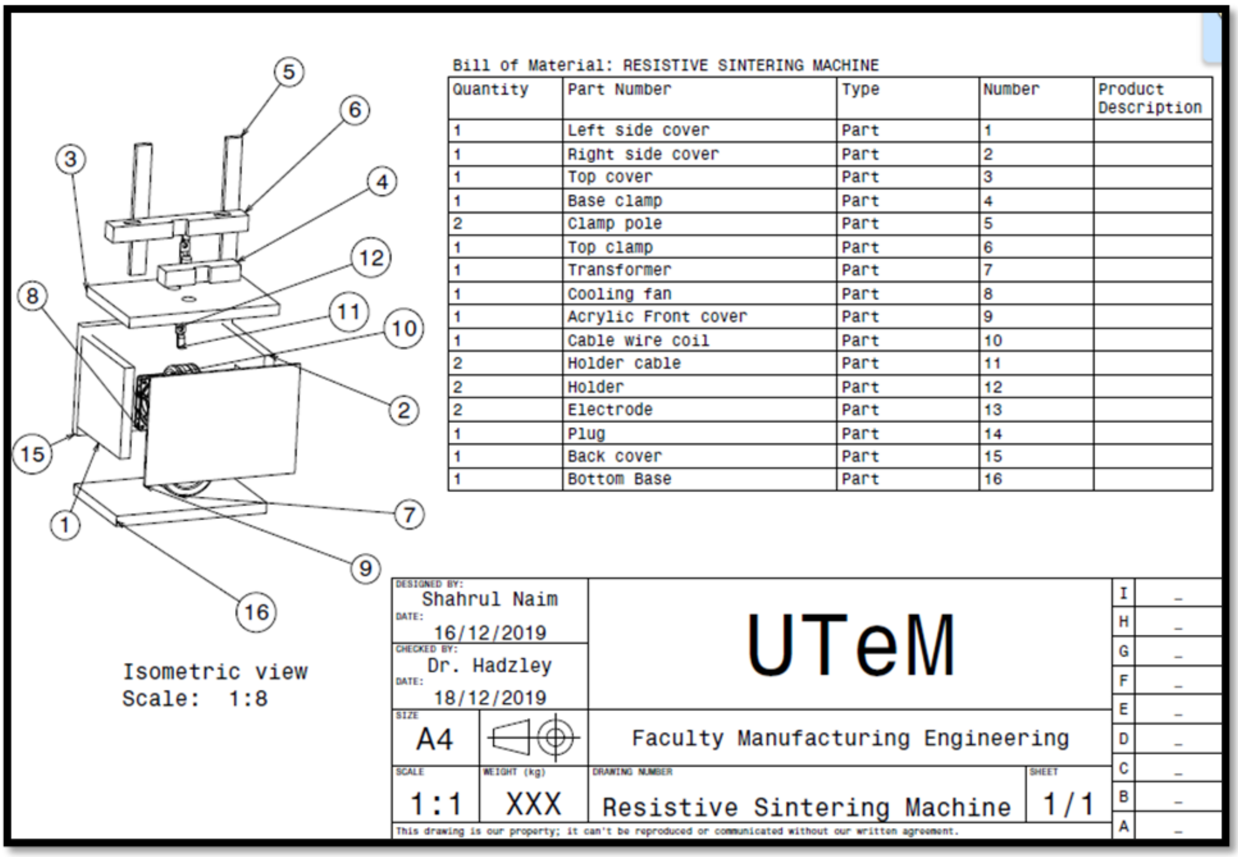


Fig. 1 - Design concept and component involved to develop resistance heating process



Bill of Material: RESISTIVE SINTERING MACHINE

Quantity	Part Number	Type	Number	Product Description
1	Left side cover	Part	1	
1	Right side cover	Part	2	
1	Top cover	Part	3	
1	Base clamp	Part	4	
2	Clamp pole	Part	5	
1	Top clamp	Part	6	
1	Transformer	Part	7	
1	Cooling fan	Part	8	
1	Acrylic Front cover	Part	9	
1	Cable wire coil	Part	10	
2	Holder cable	Part	11	
2	Holder	Part	12	
2	Electrode	Part	13	
1	Plug	Part	14	
1	Back cover	Part	15	
1	Bottom Base	Part	16	

Fig. 2 - Detail drawing of final design selection of resistance sintering furnace

Fig. 3 shows some component that involved with the machine construction. The clamp holder and the casing were assembled using screw joining. At the upper part of the machine, the electrodes were mounted on the electrode holder.

Inside the casing, the toroidal transformer was installed together with the cable wire, clamping holders and cooling fans. This machine uses single phase power supply that connected to the switch plug. Fig. 4 shows the completed resistance heating prototype that ready to perform heat treatment. In order to evaluate the temperature generation during specimen heating, thermographic camera was employed to measure the thermal change with respect to the time.

Component	**Description**
1. Toroidal transformer 	- Rated Power = 500VA - Input Voltage = 240V - Output Voltage = 100-110V - Frequency = 50Hz - Winding Material = Copper wire - Diameter of wire = 0.35mm - External diameter = 110mm - Height = 55mm - Weight = 2.5kg
2. Electrode 	- Material used = Pure copper - Good conductor - Resistivity: 1.74 – 5.01 µohm.cm - Melting temperature: 1.23e3 – 1.36e3 K

Fig. 3 - List of main components that involved to fabricate the prototype

Fig. 4 - Resistance sintering furnace after done assembly process

3. Result and Discussion

Fig. 5 shows the final product of resistance furnace machine that has been done by fabricating and manufacturing process. The core of is machine is the toroidal transformer that possess low voltage and high current. The copper cable was coiled to the transformer to accelerate the voltage at the secondary coil. Next, the cable wire attached to the electrode and the electrode were place and installed at the clamp holder. Table 1 shows the specification of the resistance sintering furnace machine that have been recorded and calculate. The power of the machine is 500 watts and the current that can achieved is about 400 amperes.

Fig. 5 - Resistance sintering furnace machine prototype

Table 1 - Specification of the machine

Specification resistance sintering furnace	
Power	560VA
Current Produced	380A-400A
Voltage	1.4V
Resistance	0.8Ω

Fig. 6 show the specimen of 22MnB5 Boron steel being tested by using newly developed resistance heating furnace machine. The specimen was placed between electrodes first before power supply switched on. The transformer generated the high current and heated up the specimen when the both electrodes touched the specimen. As the specimen heated, their microstructure was changed from pearlite to austenite. As soon as the specimen removed, the heated 22MnB5 Boron steel were placed into the 0ºC water for quenching process [12-14].

Fig. 6 - The specimen was being test and sinter using the machine x at 7 minutes, the temperature achieves 721.2°C

Fig. 7 show the pattern of the temperature generation when applying heating process to the 22MnB5 steel. The machine able to generate 134.4ºC at the first minute of operation and recorded maximum 721.2°C after 7 minutes heating duration. As the heating process prolonged, the insulation of cooper cable wire started to melt due to very high temperature generation, resulting some component seems to be overheated. Further improvement of cooper cable insulation needs to be undertaken to enhance the life of the machine [15-17].

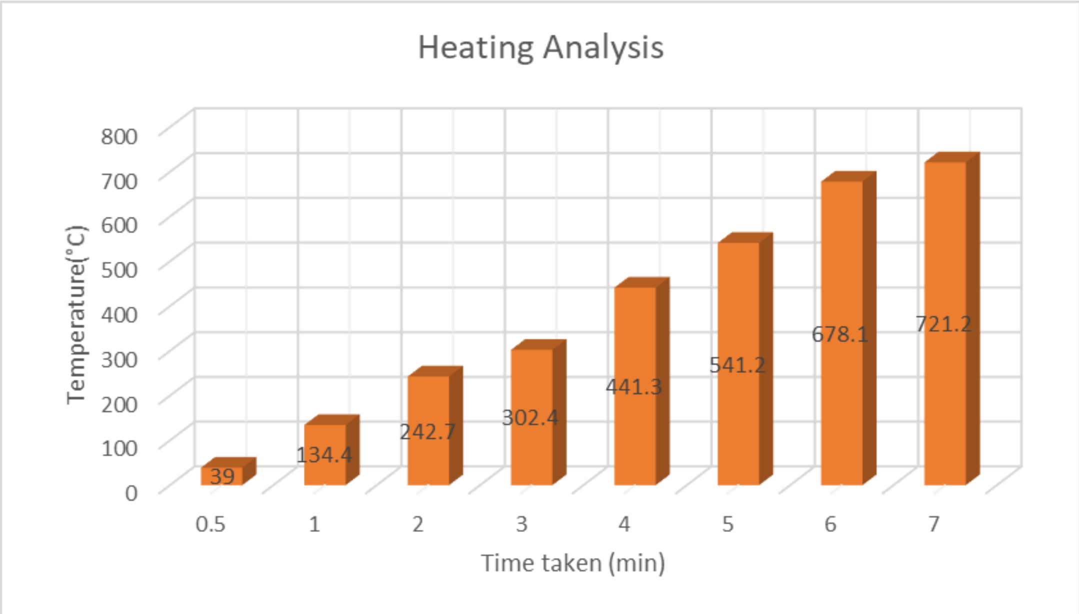


Fig. 7 - Heating analysis graph, temperature vs time taken

Conclusion

A resistance heating furnace with concept of resistance welding was development. The furnace consisted of two electrodes that mounted with casing and wood frame. The heating energy were supplied by the transformer that entangled by the cooper coil. The furnace was able to heat the 22MnB5 steel up to 721.2ºC when the 22MnB5 steel was placed between upper and lower electrodes. The furnace however, only lasted long for 7 minutes before some component overheated due to unable to resist high temperature generation. The development of furnace in this study demonstrated capability to perform heating of 22MnB5 steel with lower bergy, low cost and portable.

Acknowledgement

The authors would express their gratitude to Universiti Teknikal Malaysia Melaka (UTeM) for their support through the grant of FRGS/1/2020/FTKMP-CARE/F00438.

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