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Portable Motorcycle Vulcanizing Tool Utilizing the Exhaust Manifold Heat for Flat Repair

Redendo A. Apa Jr[1*], May Ann M. Luchavez[2], Arnulfo Ricaplaza[3], Loidan Pañares[4], Orlene C. Balungkas[5]
Department of Mechanical Engineering, University of Cebu, Cebu City, Philippines
Corresponding Author: Redendo A. Apa Jr[1]*

ABSTRACT:- This study explores the design and performance evaluation of a Portable Motorcycle Vulcanizing Tool utilizing exhaust manifold heat for vulcanizing rubber gum. The tool aims to address common flat tire issues for motorcyclists, particularly in remote areas, by offering a portable, eco-friendly alternative to traditional vulcanizing methods. Using computer-aided simulations, the study analyzed the thermal performance of three materials—Carbon Steel, Aluminum Alloy, and Copper—under varying exhaust manifold temperatures of 60°C, 120°C, 180°C, and 240°C. Results revealed that Aluminum Alloy and Copper efficiently achieved the desired vulcanizing temperature of 60°C in less than 3 minutes, with Copper demonstrating the fastest response at high thermal loads. Carbon Steel, while durable and economical, required longer times, limiting its feasibility in low-temperature scenarios.The findings suggest that Aluminum Alloy offers an optimal balance between cost and performance, making it the most practical choice for the tool's construction. The study highlights the potential of utilizing waste heat from exhaust manifolds as a sustainable energy source for tire repairs. The tool's design and thermal response fulfill the objectives of efficiency, portability, and environmental sustainability. Future improvements could focus on experimental validation, alternative material exploration, and cost analysis to enhance practical applications. This innovative approach provides a significant contribution to accessible and resource-efficient tire maintenance solutions, particularly in areas where conventional vulcanizing methods are unavailable.

Keywords:- *Portable vulcanizing tool, Exhaust manifold heat, Motorcycle tire repair, Thermal analysis, Aluminum alloy, Copper conductivity, Sustainable energy utilization, Eco-friendly vulcanization, Waste heat recovery, Flat tire maintenance*

I. INTRODUCTION

The prevalence of motorcycles as a primary mode of transportation in the Philippines has surged in recent years, highlighting the necessity for efficient maintenance solutions [1]. Among the common challenges faced by motorcyclists is the occurrence of flat tires [2], which can lead to significant delays and safety concerns [3]. Traditional tire repair methods often require bulky equipment and access to electrical power [4], limiting their applicability in remote or resource-constrained settings [5]. Innovations in portable tire repair tools have been explored, yet many still depend on external power sources or are not environmentally sustainable [6]. This scenario underscores the need for a more practical and eco-friendly approach to motorcycle tire maintenance.

Recent studies have investigated the utilization of alternative energy sources for tire vulcanization [7]. For instance, research on solar-powered vulcanizers has demonstrated potential in reducing reliance on conventional energy [8], however, their effectiveness is contingent on weather conditions and daylight availability [9]. Similarly, electronic vulcanizers offer portability but often remain dependent on battery life [10] and may not be suitable for all environments [11]. The exploration of exhaust heat as an energy source presents a novel avenue, leveraging the consistent thermal output of motorcycle engines [12]. This method aligns with sustainable practices by repurposing waste heat, thereby enhancing energy efficiency.

This study aims to develop a portable motorcycle vulcanizing tool that harnesses the heat from the exhaust manifold for tire repair [13]. By conducting thermal analyses on various materials—namely Carbon Steel, Aluminum Alloy, and Copper—the research seeks to identify the most effective medium for heat conduction to achieve optimal vulcanization temperatures [14]. The motivation behind this study is to provide motorcyclists, especially those in remote areas, with a reliable, eco-friendly, and self-sufficient tool for tire maintenance, thereby improving safety and reducing downtime during travel.

II. MATERIALS AND METHODS

The materials and methods used in this study were designed to evaluate the feasibility and performance of a portable motorcycle vulcanizing tool utilizing exhaust manifold heat. The research process involved several key components, including material selection, computer-aided design and simulation, and thermal analysis. Each step was carefully planned and executed to ensure reliability and accuracy in assessing the tool's performance.

A. Material Selection

The study explored three materials: Carbon Steel, Aluminum Alloy, and Copper, selected based on their thermal conductivity, availability, and cost [15]. Carbon Steel, while inexpensive and durable, has lower thermal conductivity, which may affect its performance in heat transfer applications. Aluminum Alloy was chosen for its lightweight properties and excellent thermal conductivity, making it a popular choice for heat transfer applications. Copper, known for its superior thermal conductivity, was included as a benchmark material for comparison. The specific grades of these materials were carefully identified to ensure compatibility with the tool's design and the thermal analysis requirements.

Different PMVT Models based on the types of Materials

Main Parts	**Materials**		
	Model 1	**Model 2**	**Model 3**
Adaptor Plate A	Carbon Steel	Aluminum Alloy 6061	**Copper**
Adaptor Plate B	Carbon Steel	Aluminum Alloy 6061	**Copper**
Tube Clamp	Carbon Steel	Aluminum Alloy 6061	**Copper**
C-Clamp	Cast Iron	Cast Iron	**Cast Iron**
M6x25 Socket Head Screw	**Stainless Steel**	**Stainless Steel**	**Stainless Steel**

PROPERTIES	**VALUE**
Density	2700kg/m^3
Melting Point	650^{o}C
Modulus of Elasticity	70Gpa
Electrical Resistivity	$0.04\times10^{-6}\Omega$.m
Thermal Conductivity	166W/m.K
Thermal Expansion	23.4×10^{-6}/K

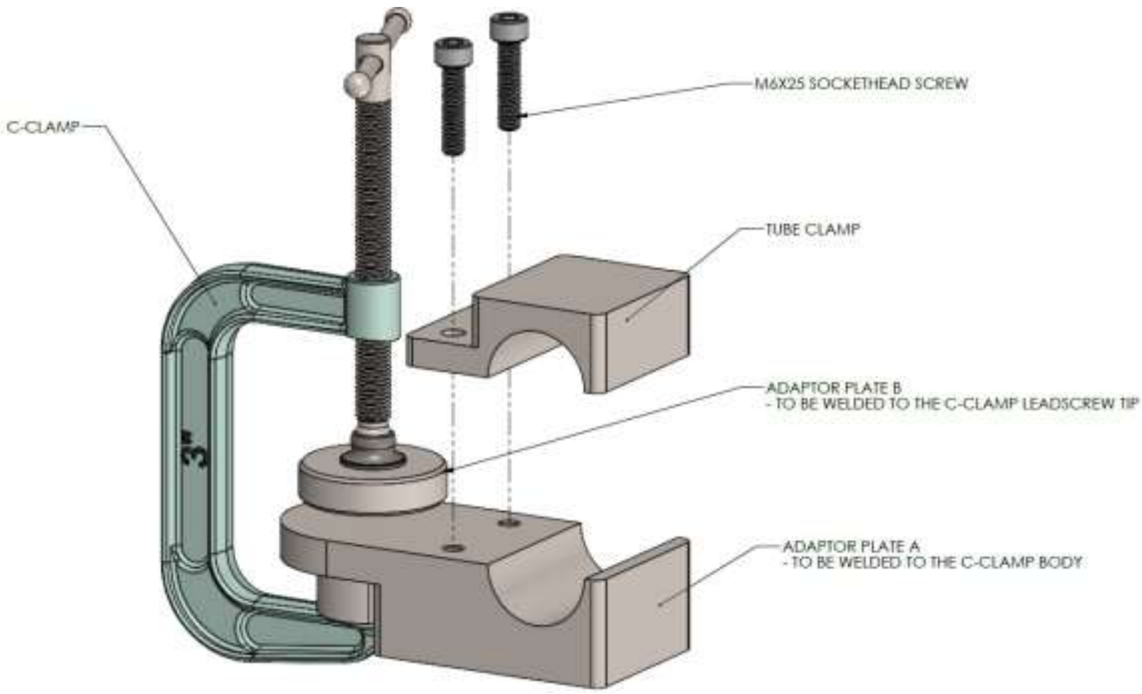
Properties of Aluminum Alloy 6061

Properties of Carbon Steel AISI 1020

PROPERTIES	VALUE
Density	7870 kg/m^3
Melting Point	$1515^O c$
Modulus of Elasticity	205 Gpa
Electrical Resistivity	$0.159 \times 10^{-6} \Omega.m$
Thermal Conductivity	51.9 W/m.K
Thermal Expansion	$11.7 \times 10^{-6}/K$

Properties of ETP Copper

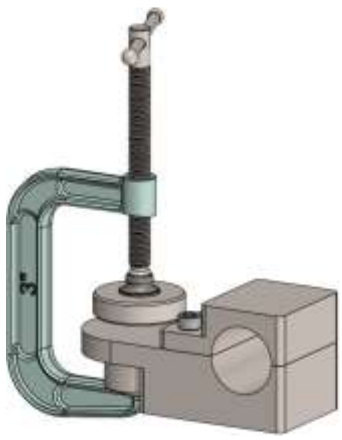
PROPERTIES	VALUE
Density	$8900 kg/m^3$
Melting Point	1083^oC
Modulus of Elasticity	120 Gpa
Electrical Resistivity	$0.0172 \times 10^{-6}\ \mu\Omega.m$
Thermal Conductivity	390W/m.K
Thermal Expansion	$17.3 \times 10^{-6}/K$



B. Tool Design and 3D Modeling

A portable motorcycle vulcanizing tool was conceptualized and modeled using SolidWorks® Premium 2018. The design consisted of critical components such as the Adaptor Plate A, Adaptor Plate B, and Tube

Clamp. These parts were modeled to ensure proper fit and functionality when attached to the exhaust manifold. The dimensions and tolerances of the components were optimized to accommodate common motorcycle exhaust manifold sizes and to facilitate efficient heat transfer [16].



C. Simulation and Thermal Analysis

Thermal simulations were conducted using SolidWorks® Flow Simulation, which allowed for the detailed evaluation of heat transfer characteristics under different conditions. The simulation parameters included:

- Thermal Loads: Exhaust manifold temperatures of 60°C, 120°C, 180°C, and 240°C.

Ambient Temperature: A baseline of 21°C, representing the minimum average ambient temperature in the Philippines. Exhaust manifold temperatures of 60°C, 120°C, 180°C, and 240°C were selected to simulate real-world scenarios of motorcycle engine operation. These temperatures represent varying levels of engine activity, from idle conditions to extended high-performance usage. The selection of these specific temperature points ensures that the tool's feasibility can be evaluated across a broad spectrum of realistic operating environments. Additionally, this range covers the minimum required temperature for vulcanization (60°C) and provides insights into the efficiency of heat transfer at higher temperatures [17]. By including these variations, the study ensures that the tool is effective under both standard and extreme operating conditions.

- Mesh Settings: High-quality solid mesh with 144,817 nodes and 9,105 elements to ensure detailed thermal distribution analysis.

Twelve trials were performed, combining the three materials with the four exhaust manifold temperature settings. The analysis focused on the time required to achieve the desired vulcanizing temperature of 60°C on the adaptor plate's surface [18]. The thermal conductivity, specific heat, and density of each material were integrated into the simulation to provide accurate results.

D. Data Collection and Statistical Analysis

Temperature distribution data were collected at specific nodes on the tool's adaptor plate over time. Each trial's data were tabulated and graphed to illustrate the thermal response of each material under varying conditions. Statistical tools were used to compare the performance of the materials and validate the results, ensuring the reproducibility and reliability of the findings [19].

E. Limitations and Assumptions

The study was conducted entirely through computer simulations, with no physical prototypes tested. It was assumed that the exhaust manifold maintained a consistent temperature during operation and that ambient temperature fluctuations did not significantly impact the results. Future research is recommended to validate these findings through physical experimentation and to explore additional materials that may offer cost-effective yet efficient heat transfer.

By combining rigorous simulation techniques with a systematic approach to material selection and design, this study provided a comprehensive evaluation of the proposed vulcanizing tool's performance and feasibility.

III. RESULTS AND DISCUSSION

The results of this study are based on the thermal simulations conducted to evaluate the performance of the Portable Motorcycle Vulcanizing Tool using three materials—Carbon Steel, Aluminum Alloy, and Copper—across four exhaust manifold temperature settings (60°C, 120°C, 180°C, and 240°C). Key parameters such as time to reach vulcanizing temperature, material efficiency, and adaptability under different thermal loads were analyzed. The findings are presented with supporting Figures to highlight the critical outcomes [20].

Each simulation result allowed the researchers to see the temperature distribution over a period using different materials, and heat source [21]. The results of trials from 1 to 12 are presented through images of temperature distribution with node details and time curves [22].

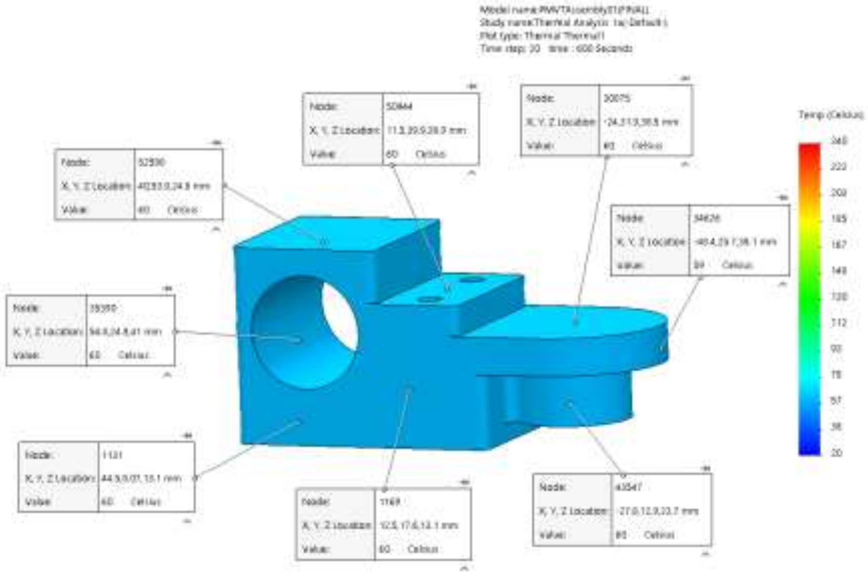


Figure 1. Temperature Distribution Trial 1 at time, t=600 sec

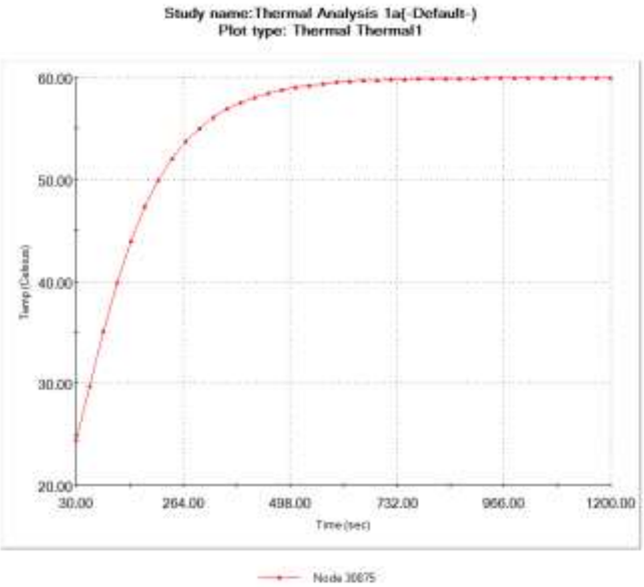


Figure 2. Time-curve Trial 1 at node 30875

Based on the results from trial 1 as shown on figures 1 and 2, it shows that when using the Portable Motorcycle Vulcanizing Tool made of Carbon Steel at exhaust header surface temperature of 60ºC, it would take at least 600 seconds (or 10 minutes) to reach the desired vulcanizing gum temperature of 60ºC.

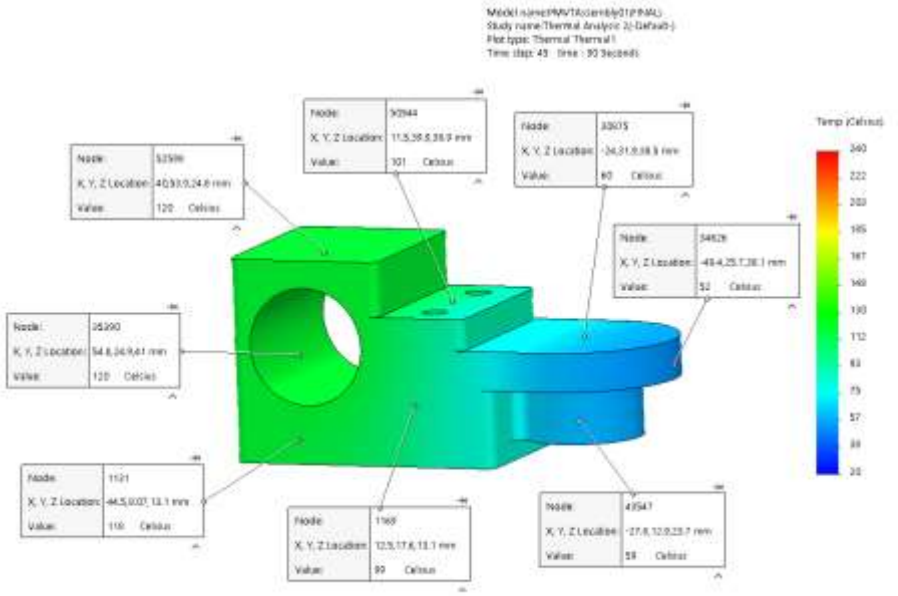


Figure 3. Temperature Distribution Trial 2 at time, t=90 sec

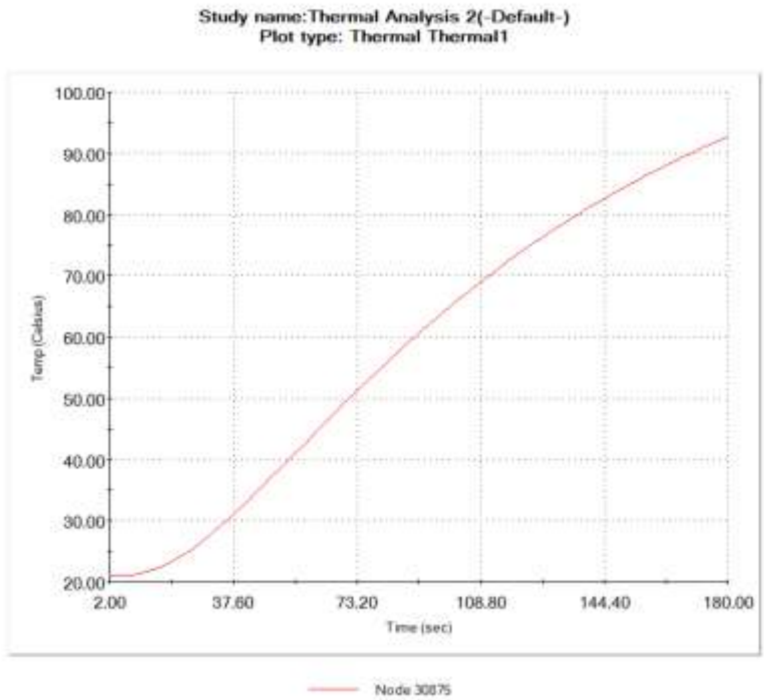


Figure 4. Time-curve Trial 2 at node 30875

Based on the results from trial 2 as shown on figures 3 and 4, it shows that when using the Portable Motorcycle Vulcanizing Tool made of Carbon Steel at exhaust header surface temperature of 120ºC, it would take at least 90 seconds (or 1 min and 30 sec) to reach the desired vulcanizing gum temperature of 60ºC.

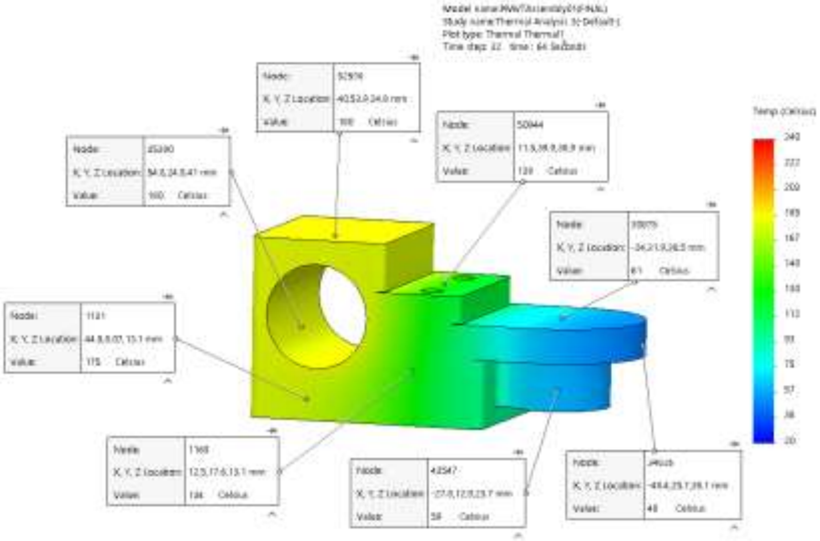


Figure 5. Temperature Distribution Trial 3 at time, t=64 sec

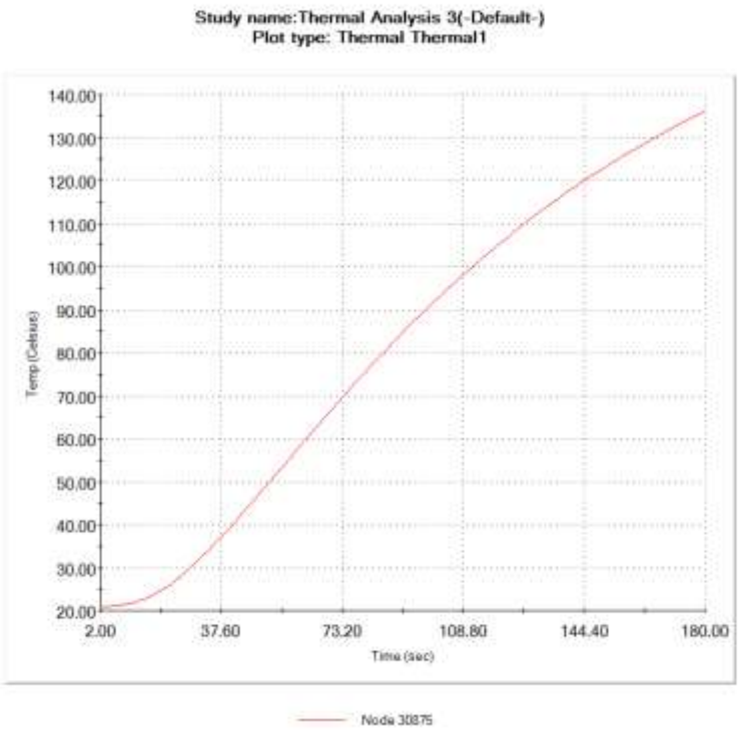


Figure 6. Time-curve Trial 3 at node 30875

Based on the results from trial 3 as shown on figure 5 and 6, it shows that when using the Portable Motorcycle Vulcanizing Tool made of Carbon Steel at exhaust header surface temperature of 180ºC, it would take at least 64 seconds (or 1 min and 4 sec) to reach the desired vulcanizing gum temperature of 60ºC.

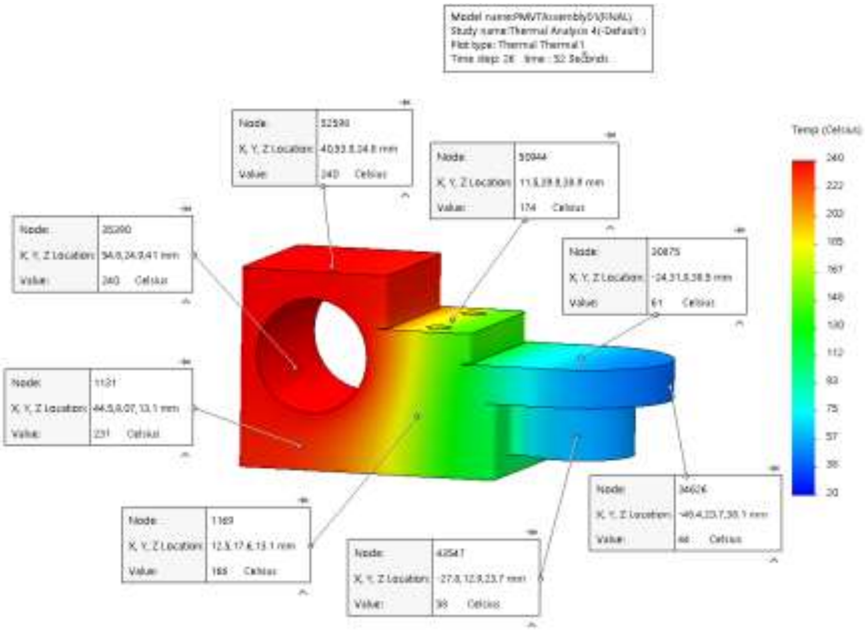


Figure 7. Temperature Distribution Trial 4 at time, t=52 sec

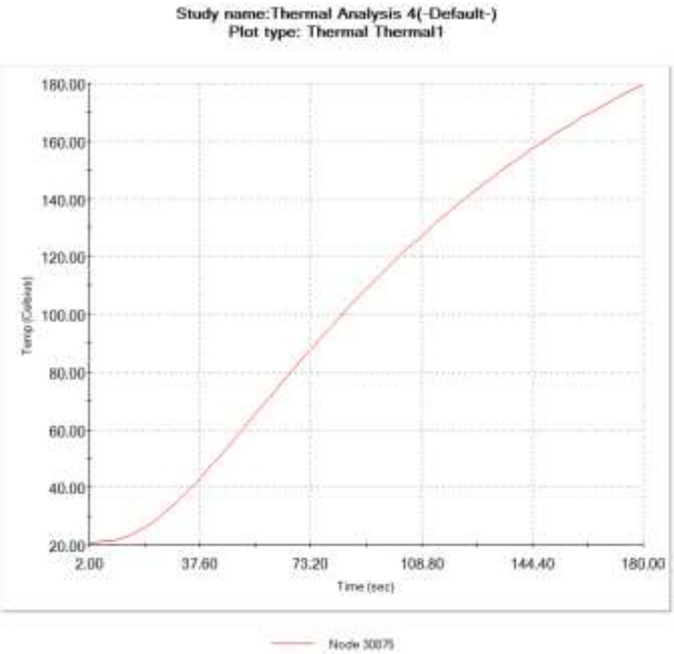


Figure 8. Time-curve Trial 4 at node 30875

Based on the results from trial 4 as shown on figures 7 and 8, it shows that when using the Portable Motorcycle Vulcanizing Tool made of Carbon Steel at exhaust header surface temperature of 240ºC, it would take at least 52 seconds to reach the desired vulcanizing gum temperature of 60ºC.

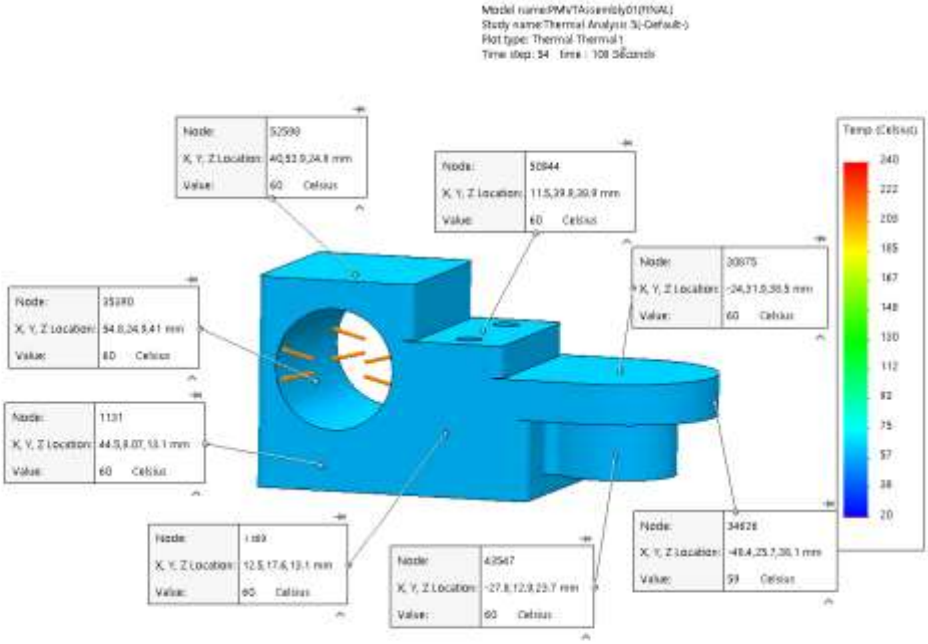


Figure 9. Temperature Distribution Trial 5 at time, t=108 sec

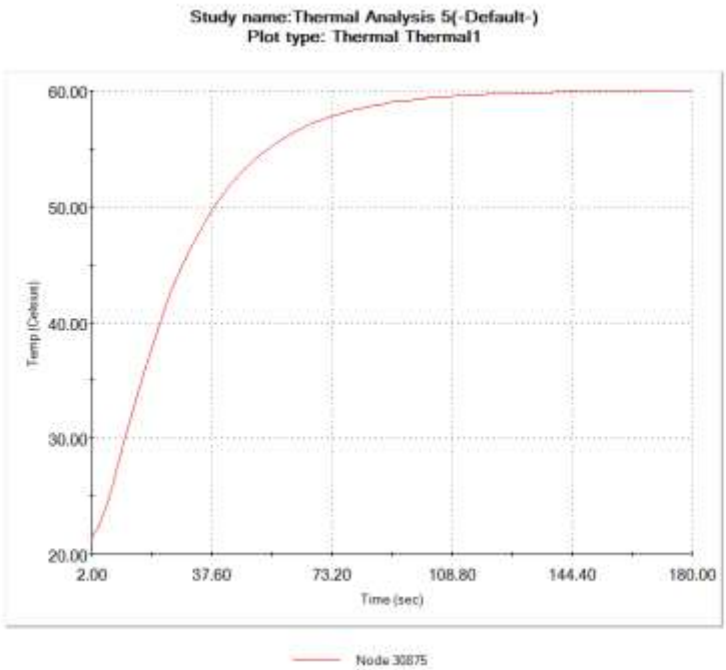


Figure 10. Time-curve Trial 5 at node 30875

Based on the results from trial 5 as shown on figures 3.5a and 3.5b shows that when using the Portable Motorcycle Vulcanizing Tool made of Aluminum Alloy at exhaust header surface temperature of 60ºC, it would take at least 108 seconds (or 1 min and 48 sec) to reach the desired vulcanizing gum temperature of 60ºC.

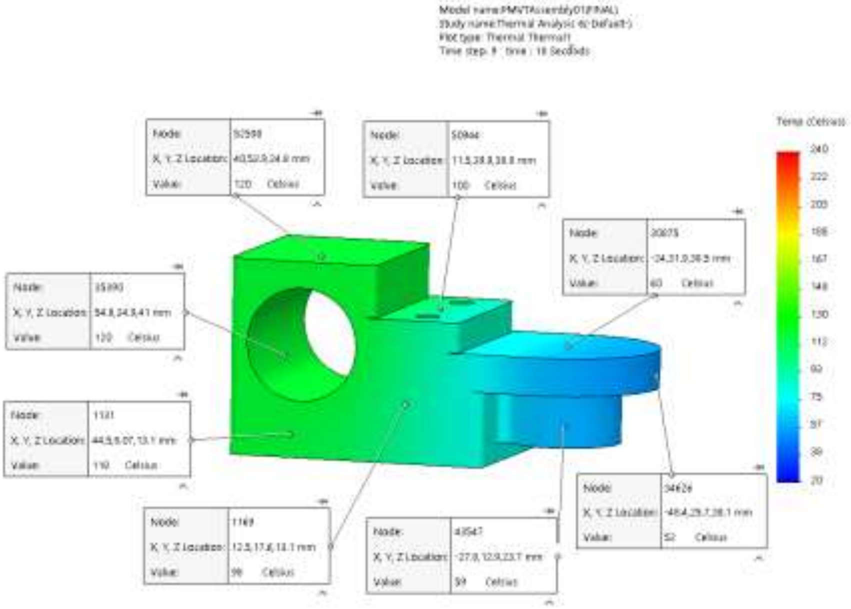


Figure 11. Temperature Distribution Trial 6 at time, t=18 sec

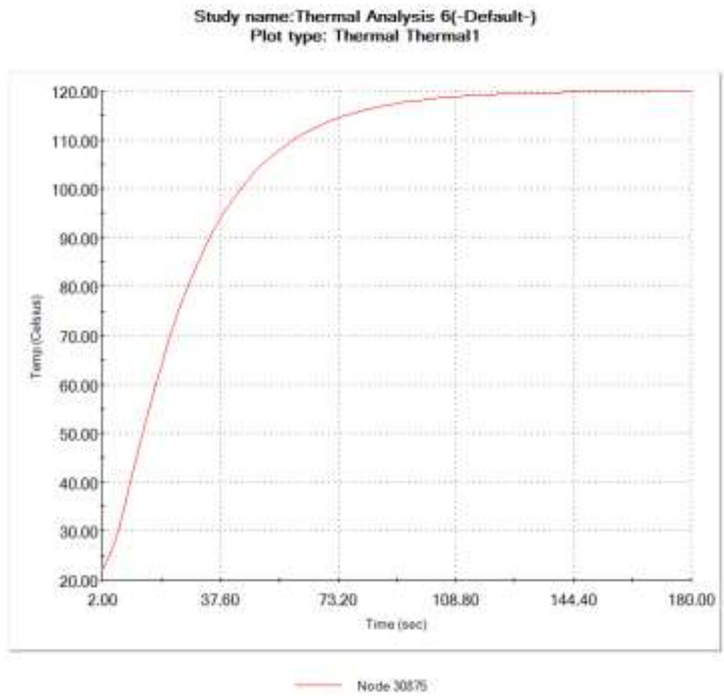


Figure 12. Time-curve Trial 6 at node 30875

Based on the results from trial 6 as shown on figures 3.6a and 3.6b shows that when using the Portable Motorcycle Vulcanizing Tool made of Aluminum Alloy at exhaust header surface temperature of 120ºC, it would take at least 18 seconds to reach the desired vulcanizing gum temperature of 60ºC.

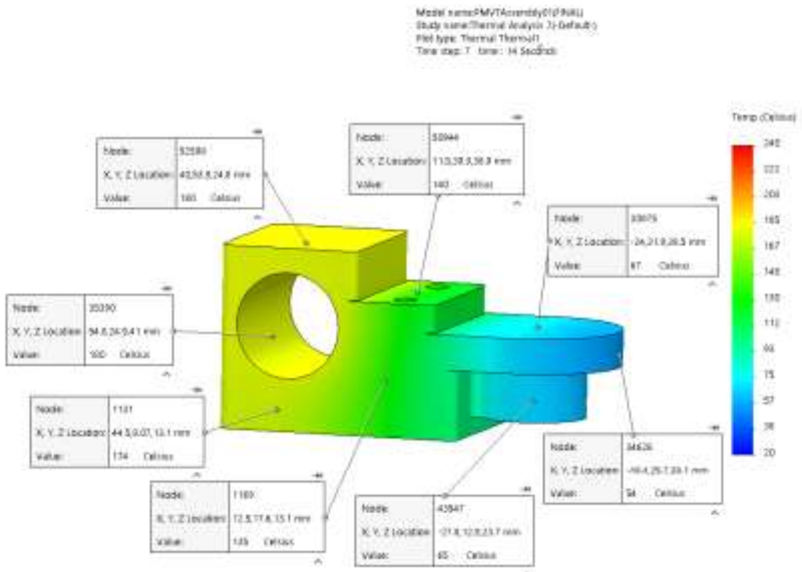


Figure 13. Temperature Distribution Trial 7 at time, t=14 sec

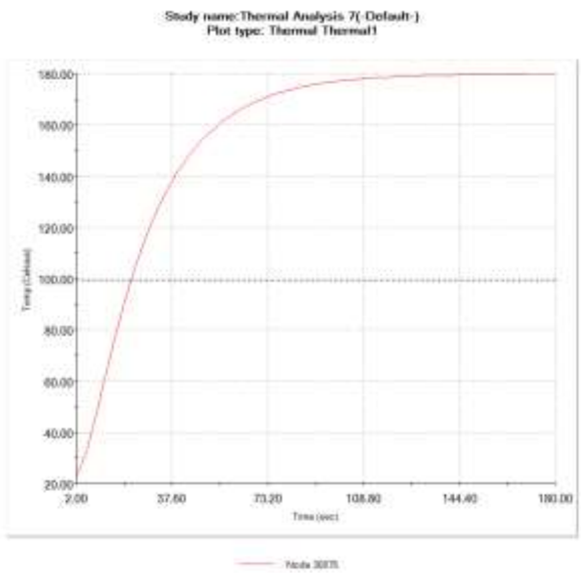


Figure 14. Time-curve Trial 7 at node 30875

Based on the results from trial 7 as shown on figures 13 and 14 shows that when using the Portable Motorcycle Vulcanizing Tool made of Aluminum Alloy at exhaust header surface temperature of 180ºC, it would take at least 14 seconds to reach the desired vulcanizing gum temperature of 60ºC.

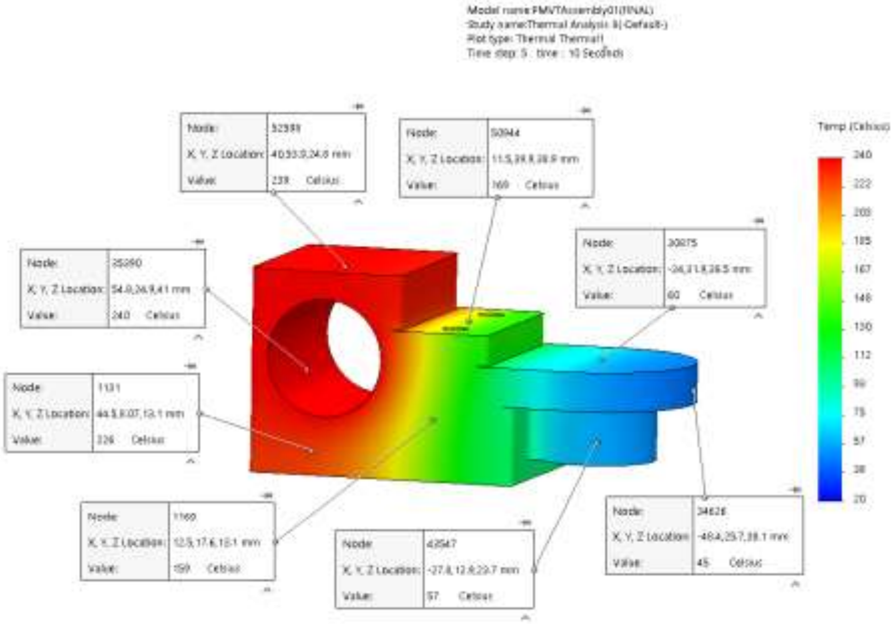


Figure 15. Temperature Distribution Trial 8 at time, t=10 sec

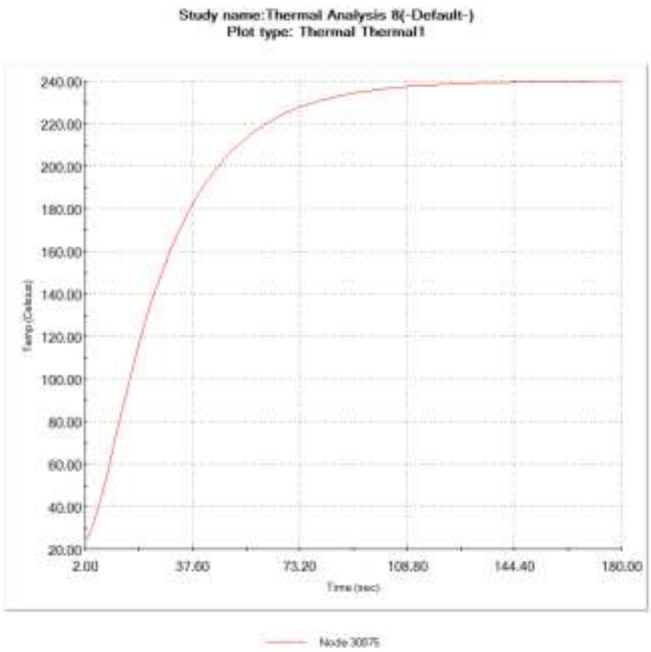


Figure 16. Time-curve Trial 8 at node 30875

Based on the results from trial 8 as shown on figures 3.8a and 3.8b shows that when using the Portable Motorcycle Vulcanizing Tool made of Aluminum Alloy at exhaust header surface temperature of 240ºC, it would take at least 10 seconds to reach the desired vulcanizing gum temperature of 60ºC.

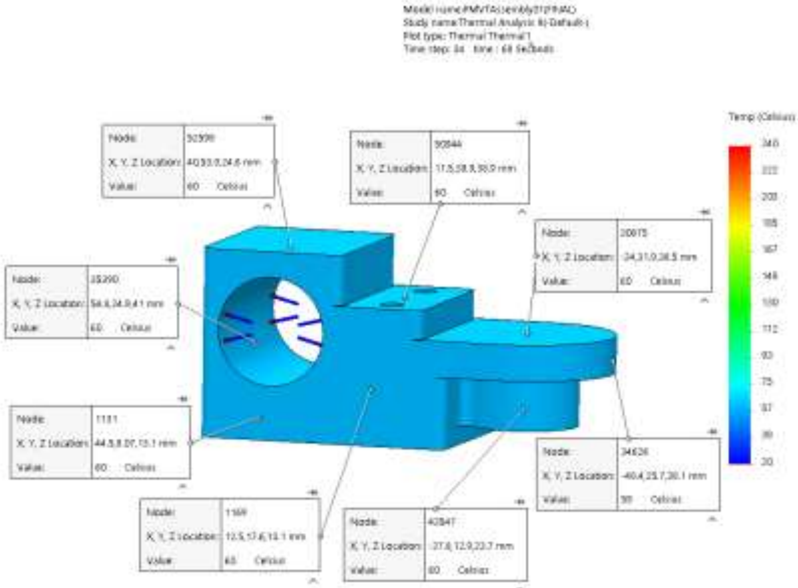


Figure 17. Temperature Distribution Trial 9 at time, t=68 sec

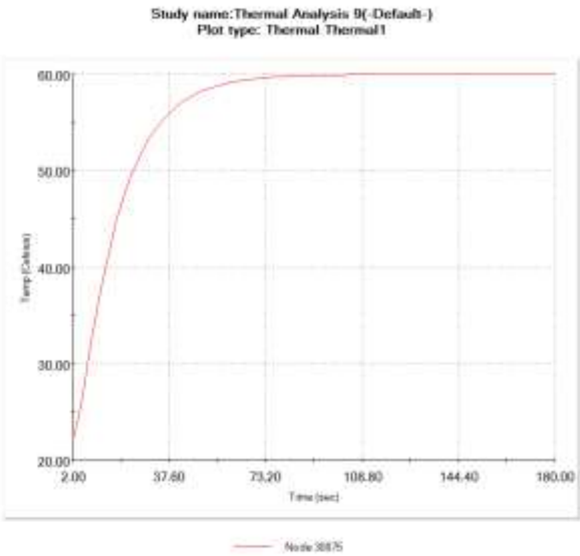


Figure 18. Time-curve Trial 9 at node 30875

Based on the results from trial 9 as shown on figures 17 and 18 shows that when using the Portable Motorcycle Vulcanizing Tool made of copper at exhaust header surface temperature of 60ºC, it would take at least 68 seconds (or 1 min and 8 sec) to reach the desired vulcanizing gum temperature of 60ºC.

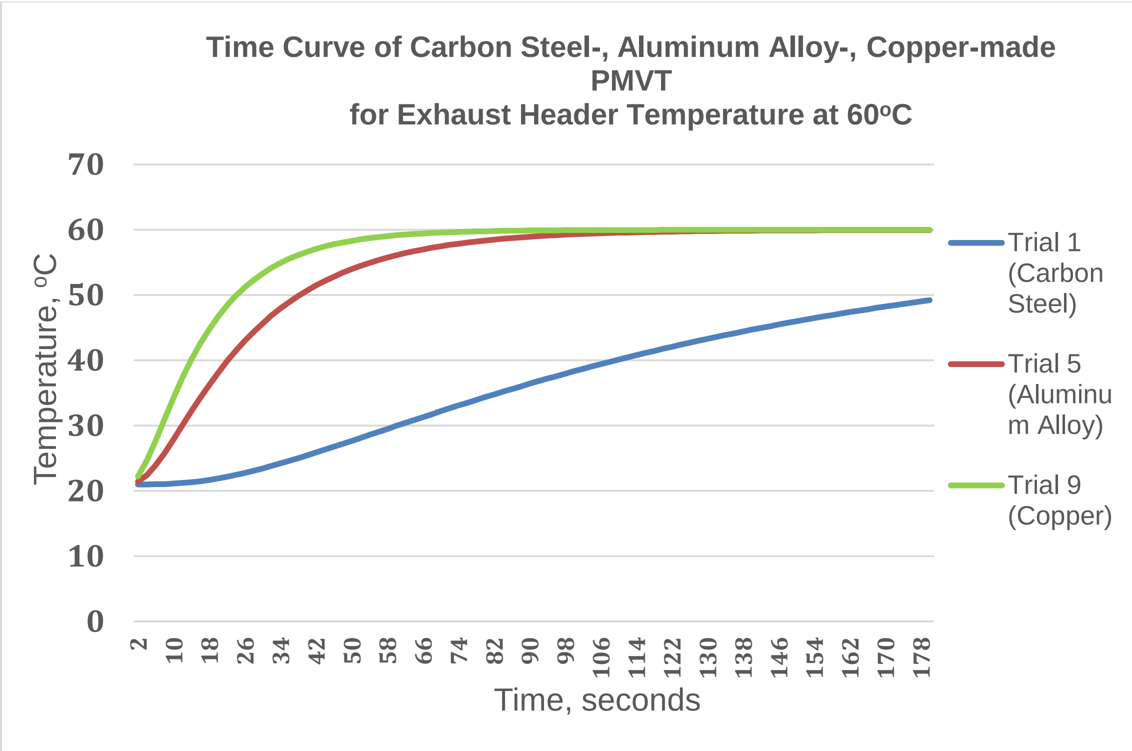


Figure 19. Comparison of results of Trials 1, 5, and 9

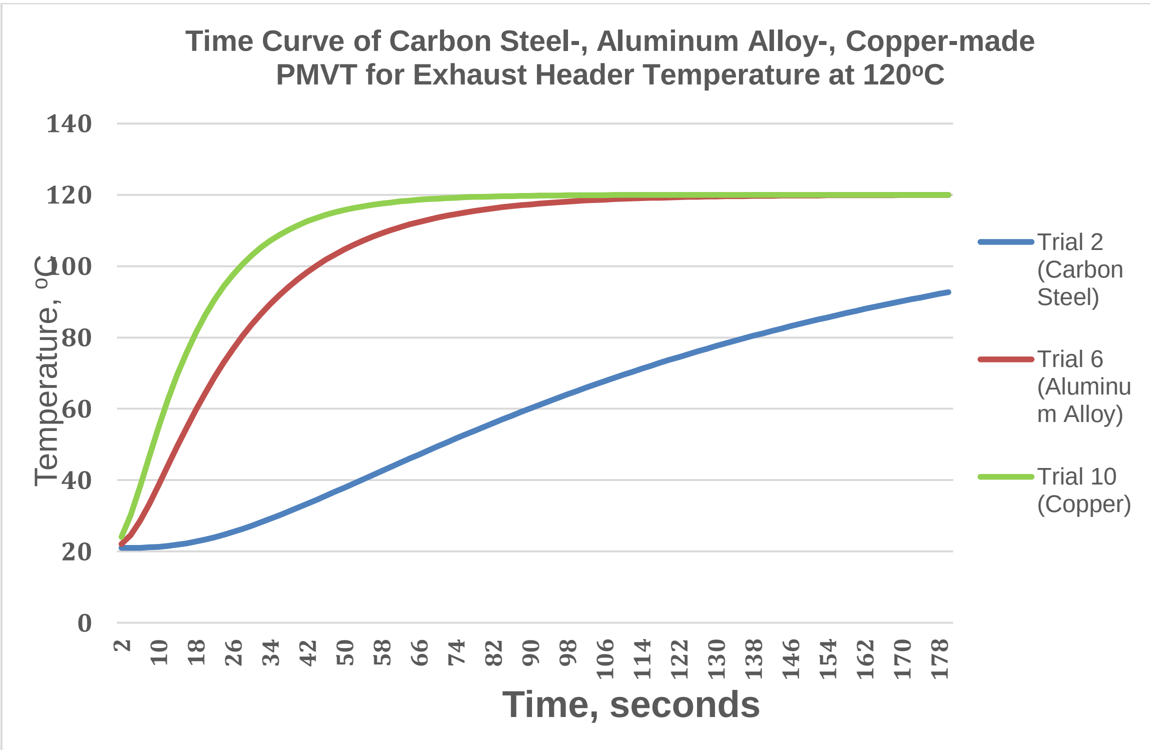


Figure 20. Comparison of results of Trials 2, 6, and 10

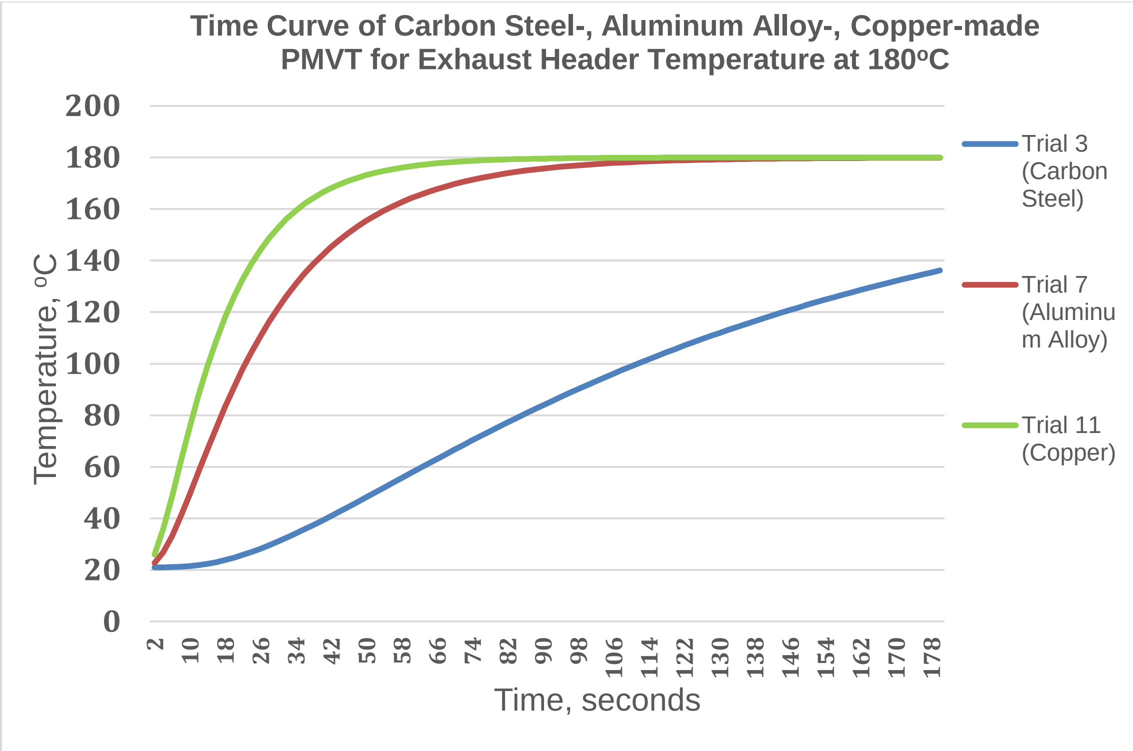


Figure 21. Comparison of results of Trials 3, 7, and 11

Figures19, 20, 21, and 22 show that Copper- and Aluminum Alloy-made portable motorcycle vulcanizing tool will reach the same temperature as the exhaust header in less than 3 minutes given thatthe header's surface temperature will not be lesser than 60ºC, which is the desired temperature to exactly bond the rubber gum to the tire interior [23].

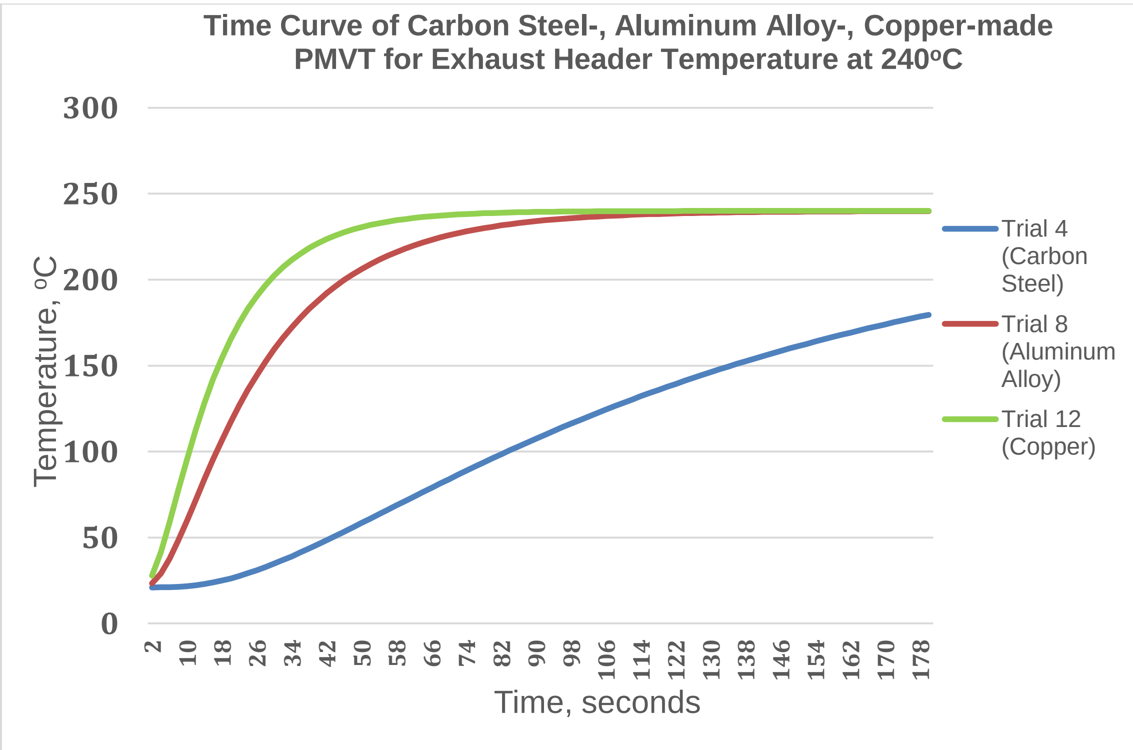


Figure 22. Comparison of results of Trials 4, 8, and 12

It is also shown in figure 22 that Carbon Steel-made tool would take a little longer to reach the 60ºC rubber gum vulcanizing temperature when the exhaust header surface temperature is lesser than 120ºC. However, it would take less than 3 minutes also for Carbon Steel-made tool to reach the desired temperature of adaptor plate (node 30875) to 60ºC when the exhaust header surface temperature is at least 120ºC.

IV. CONCLUSION

The study's findings reveal critical insights into the thermal performance of the proposed Portable Motorcycle Vulcanizing Tool. Among the three materials tested—Carbon Steel, Aluminum Alloy, and Copper—Copper consistently demonstrated superior thermal conductivity, achieving the desired vulcanizing temperature of 60°C in the shortest time, particularly under high exhaust manifold temperatures (e.g., 240°C, where it took only 8 seconds). Aluminum Alloy also exhibited efficient heat transfer properties, requiring 18 seconds to reach 60°C at 120°C exhaust temperature, making it a cost-effective alternative to copper. Conversely, Carbon Steel, while durable and economical, proved less effective in scenarios with low exhaust temperatures, taking up to 10 minutes to achieve the target temperature. The thermal response of Aluminum Alloy and Copper across various temperature ranges indicates their suitability for practical applications, ensuring rapid vulcanization during roadside emergencies. This suggests that future tools designed for efficiency and affordability should prioritize these materials, especially Aluminum Alloy, given its balance between performance and cost.The study successfully achieved its objectives by designing and simulating a portable vulcanizing tool that effectively utilized exhaust manifold heat for tire repair. The results confirmed that the tool could achieve the desired vulcanizing temperature of 60°C in less than 3 minutes with Aluminum Alloy and Copper, meeting the performance criteria for efficiency and portability. Improvements can include incorporating additional material options, such as advanced thermal alloys, to further optimize performance and reduce cost. Another recommendation is to integrate experimental validation to confirm simulation results and enhance reliability under real-world conditions. Overall, the research highlights the feasibility of a compact, environmentally friendly vulcanizing tool that addresses the critical need for accessible tire repair solutions, particularly in remote or underserved areas.

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Corresponding Author: Redendo A. Apa Jr[1*]
Department of Mechanical Engineering, University of Cebu, Cebu City, Philippines