Proposal for Arduino-based experimental for the study of unsteady heat transfer temperature of metals

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Abstract

This experiment aims to investigate the rate of temperature change of a metal cylinder in unsteady heat transfer between two heat sources, and to investigate the relationship between the experimental hypotheses and the temperature of the heat source, its location, length, material and other factors. The completion of this experiment will contribute to the study and understanding of unsteady-state heat transfer.

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1 Background of Research

Metal in the process of heat conduction, before reaching thermal equilibrium, will be in an unsteady heat conduction process. [**?**] In this process, the temperature of the metal will be affected by multiple surface factors. This process is very common in real life: when the power machinery starts, stops and operates under varying conditions, the rapid temperature change will destroy the parts due to thermal stress, so it is necessary to determine the instantaneous temperature field inside the object: the heat treatment of the steel prick workpiece is a typical unsteady heat conduction process, controlling the rate of temperature change in the workpiece is an important factor to control the quality of workpiece heat treatment. For example, when the metal is heated in the heating furnace, it needs to determine the time it stays in the heating furnace to ensure that the specified temperature is reached. [**?**] Therefore, unsteady heat conduction is a topic of great practical significance.

Through the use of real-time feedback data and precision measurement of the Arduino experimental platform for data acquisition, we can improve the accuracy and scientific nature of the experiment.

To verify the relationship between temperature change rate and various factors, the following hypotheses will be given as the basic content of the experiment:

1. Before reaching the steady-state, the speed of temperature change at the point becomes faster with the enhancement of thermal conductivity of the material.

2. Before reaching a steady-state, the rate of temperature change at the point becomes faster with the shortening of the metal length.

3. Before reaching the steady-state, the speed of temperature change at the point becomes faster with the increase of heat source temperature.

4. Before reaching the steady-state, the speed of temperature change at the point becomes faster with the decrease of heat source distance.

This experiment adopts the quantitative analysis method and control variable method to control each variable, and sets up several experimental groups for the experiment, and verifies the qualitative and quantitative relationship between each variable through data analysis.

Compared with traditional methods [**?**], Arduino and high-precision sensors were used in this experiment to measure data in real-time, which greatly improved the accuracy of the experiment.

2 Research Objective

This experiment aims to study heat conduction on a metal rod and external factors which act inferences on it. By manipulating controlled variables, we will act experiments to understand this process.

The experiment will be divided into three experimental groups according to the hypotheses and will measure the effects of length, material and temperature difference on the temperature change and will be able to determine the distance from the heat source in hypothesis 4 by using the data from the three groups. This makes the experiment scientifically feasible.

The experiments were carried out using two materials, a combination of length variation, temperature variation by adjusting the temperature of the domestic kettle, and six sensors set at different locations to collect the temperature variation at different distances.

The experiments will focus on these variables, while using the data generated to obtain additional phenomena and conclusions beyond the hypothesis, to investigate the variation of temperature in the heat transfer of metals in a non-stationary state.

3 Research Methodology

By quantitative analysis, we collect data through experiments and using computational simulation software COMSOL to carry out the theoretical simulation of the whole process to auxiliary our experiment.

The research object of our experiment is the rate of temperature change with time on certain points on the metal rod, therefore, variables of our experiment are:

1. Material of the metal rod
2. Temperature differences between two edge
3. Length of the metal bar (measurement point will change with it in a percentage rate)

Our experiment runs by controlling variables. We set our experiments as below:

set	1	2	3	4	5
material	Fe	Fe	Fe	Fe	Fe
length	25	25	25	25	25
temperature difference	60	70	80	90	100
set	6	7	8	9	10
material	Cu	Cu	Cu	Cu	Cu
length	25	25	25	25	25
temperature difference	60	70	80	90	100
set	11	12	13	14	15
material	Cu	Cu	Cu	Cu	Cu
length	50	50	50	50	50
temperature difference	60	70	80	90	100

Figure 1: Experiments Plan

By controlling all the variables, we will conclude all hypotheses.

3.1 Instruments

1. Arduino board: for data processing and recording, and for connecting the various sensors;
2. TMP36GT9Z temperature sensor: used to detect the temperature data of each point and send it back to Arduino in real-time;
3. Steel and copper metal rods: 10mm diameter, 250mm length, two each, as the object of the experiment, connected to both sides of the thermal conductivity of the copper sheet for measurement;

4. Thermally conductive copper sheet: used to connect the heat source (hot water and ice water mixture) with the metal rod;

5. Household thermostat heater: used as a heat source on the higher side of the temperature, which can be maintained at the set temperature.

Our experiment will use Arduino UNO as a data collecting tool. It possesses 6 simulation signal input ports, so we can install 6 sensors on our metal rod isometrically. Arduino will be connected to our computer and upload temperature data measured by sensors at the frequency we set up.

In our experiments, we will use 10mm*250mm metal rods made of copper and steel with high thermal conductivity to make the experimental phenomena more visible. [**?**] Both sides of the metal rod will be polished and connected to a copper sheet for its good quality at heat-conducting. Two copper sheets will be placed into constant temperature water and each side maintains a certain temperature difference. The temperature sensors will be mounted on 1/2, 1/4, 3/4, 1/8 and metal sheets, which will ensure the maximum application of the measured data.

In the experiment, we will carry out the circuit and equipment assembly according to the advance plan. In the experiment, we will stick the temperature sensing on the metal rod and fix the metal with rubber bands, etc., and preheat the heat source and the metal piece first, until the sensor on the metal piece shows that it reaches the required temperature and remains unchanged for a long time, and install the metal rod between it. Start the experiment and start the data acquisition program. The experiment will be carried out until the temperature indication is stable for a long time (i.e. the metal enters a steady-state) and then ends.

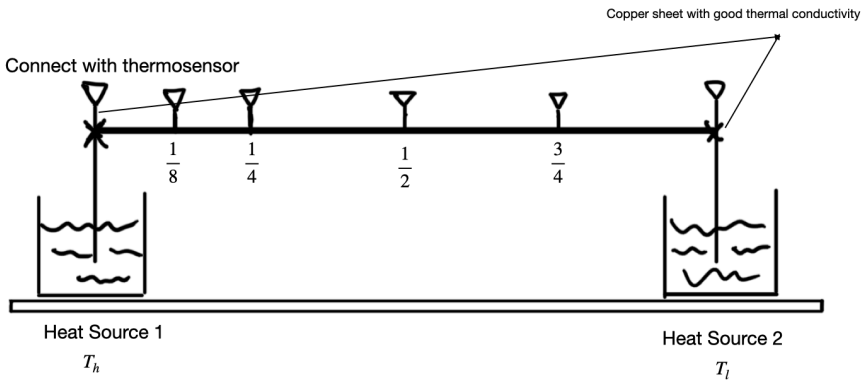

Figure 2: Single Metal Stick

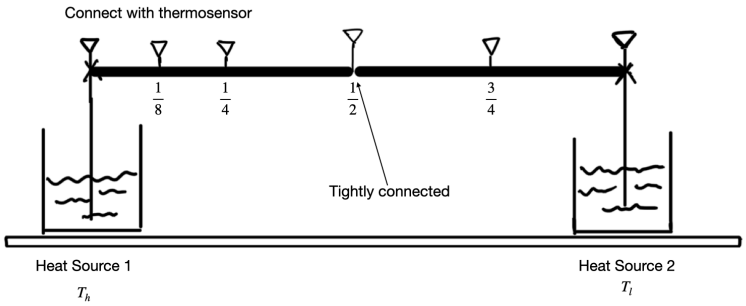

Figure 3: Double Metal Stick

3.2 Data collecting

In the experiment, we use Arduino and temperature sensors to collect data and send it back to a computer in real-time and record the time. Each experiment will be conducted 3 times, and when there is a large difference, the experiment will be redone. Since the experiment may be conducted in different locations, the data from each location will be processed separately, in the same way, to ensure that the experiment will not be interfered with by climatic factors.

The experiment started after the metal rod and the copper heat-conducting sheet were completely pressed against each other and ended when the temperature at each point did not change for a long time.

3.3 Data analyzing

With the time data collected and the corresponding temperature at each point, we will have the ability to plot the image of the temperature at each point with time and fit the image of the temperature at the same time point with the position. By taking the average slope as well as the maximum slope of the former and comparing it horizontally among the experimental groups, we will be able to draw the relationship between it and other factors and judge the hypothesis; by the latter with the change of time, the temperature change of the metal can be studied more deeply and more conclusions will be obtained.

For our experiment will be simulated on COMSOL with the whole process, we will get high-accuracy theoretical data, and these data can help us to do error analysis. After we sort out factors that might affect our experimental results, we can improve our experiment.

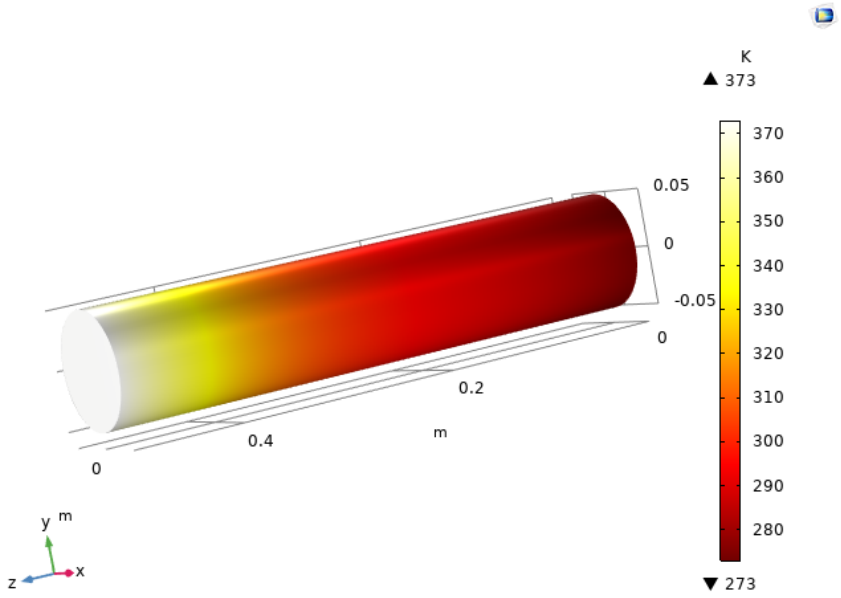

Figure 4: Budget Planning Chart

4 Milestone and Gantt Chart

Milestone 1 Experimental set-up design completed

Milestone 2 Experimental circuit construction completed

Milestone 3 Experimental program and data processing program written

Milestone 4 Virtual COMSOL experiment completed

Milestone 5 Experimental investigation into the relationship between point temperature change and heat source temperature completed

Milestone 6 Experiment to investigate the relationship between temperature change at a point and length completed

Milestone 7 Experimental investigation into the relationship between point temperature change and point location completed

Milestone 8 complete a class 1 lab report

Milestone 9 Interim report submitted

Milestone 10 examine the relationship between the temperature at each point of the steady-state (especially the middle series) and the temperature of the heat source at each end

Milestone 11 check the temperature at each point of the steady-state (especially the middle series point) in relation to the order of the material connection Experiment completed

Milestone 12 Complete Data Analyse

Milestone 13 Submission of the overall experimental report

Milestone 14 Complete 2 types of experimental reports

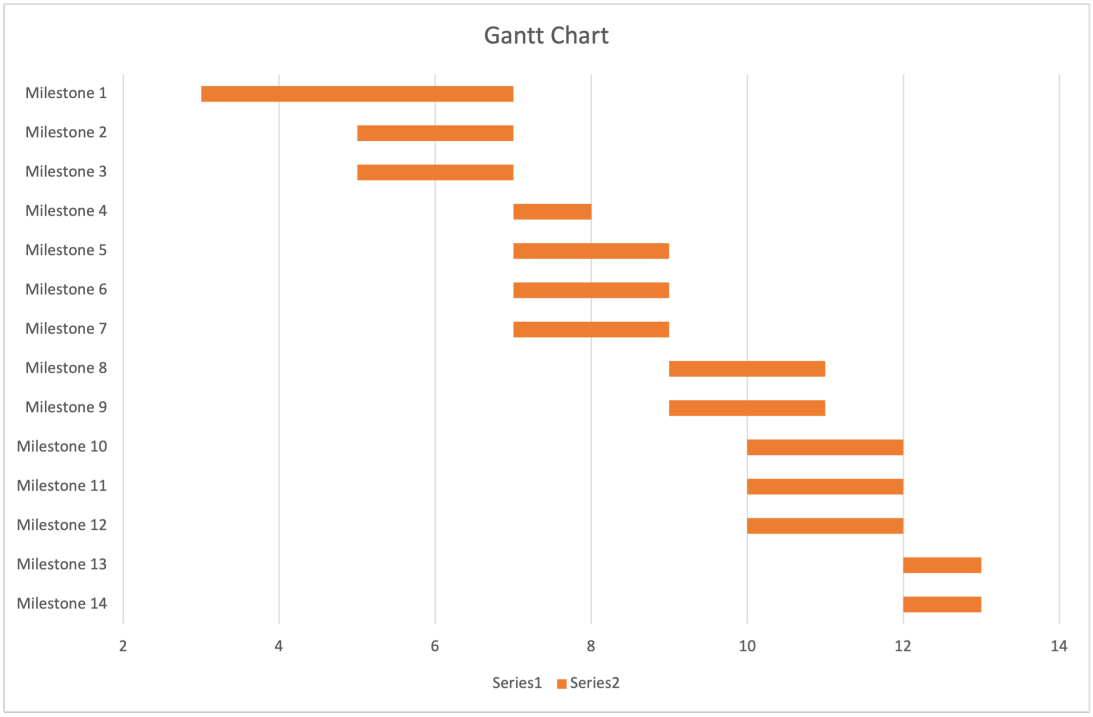

Figure 5: Gantt Chart

5 Budget Planning

Unpredictable budget factor 1 Missing circuit parts due to damage or redesign of the circuit

Unpredictable budget factor 2 Unavailability due to damage, re-purchase due to unsuitable size. Metal bar prices exceed expectations

Name	Purchase Link	Amount	Unit	Price(RMB)	Price(RM)	Total(RM)
Circuit Part						
Arduino Nano Third party board	https://m.tb.cn/h.f3TMdzy?sm=1180a3	3	Piece	14.6	9.49	28.47
Arduino Nano expansion board	https://m.tb.cn/h.f3TK3Hb?sm=334572	3	Piece	8	5.2	15.6
Temperature Sensor(TMP36GT9Z)	https://m.tb.cn/h.f325opR?sm=242b49	1	100/pack	8	5.2	5.2
Dupont Line	https://m.tb.cn/h.fW4XhpE?sm=cc6834	3	group(40+40)	12	7.8	23.4
Other circuit element(Resistor)	https://m.tb.cn/h.f326lzq?sm=b39ef3	3		5	3.25	9.75
Unpredictable factor 1		1		20	13	13
Material Part					0	0
Iron Stick(10mm,0.25m)	The shop not decided	12	stick	5	3.25	39
Copper Stick(10mm,0.25m)	The shop not decided	12	stick	7	4.55	54.6
Copper Sheet(0.mm,0.25m)	The shop not decided	9	piece	3.25	2.1125	19.0125
Other meterial(binder,sandpaper,support stand)	The shop not decided	3	group	12	7.8	23.4
Unpredictable factor 2		1			50	50
Logistics cost(Delivery cost,Package)		1		25	16.25	16.25
					0	0
sum						297.6825

Figure 6: COMSOL-based non-stationary temperature conduction model for cylinders

A Relevant Chart

The all EXCEL chart could be find: https://git.io/JrY5m

B Screenshot of Equipment Offer

Figure 7: Arduino Nano Board

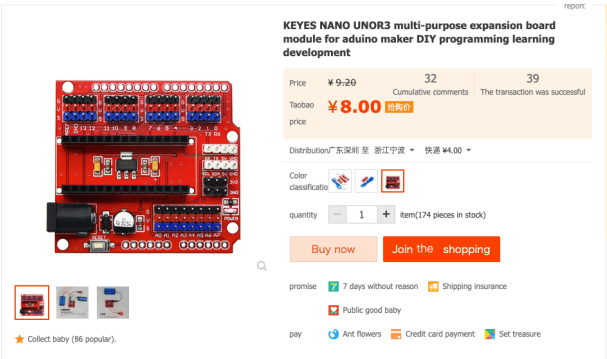

Figure 8: Arduino Nano Expansion Board

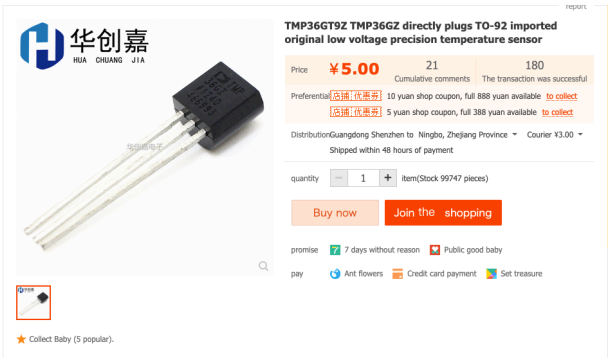

Figure 9: TMP36 Sensor

Figure 10: Dupont Line