Automatic Dishwashing Machine

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A thesis submitted in partial fulfillment of the requirements for the degree of Bachelors of Engineering in Mechanical Engineering

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June, 2016

National University of Sciences & Technology

FINAL YEAR PROJECT REPORT

We hereby recommend that the dissertation prepared under our supervision by: Waleed Mehdi (NUST201200330), Hamza Rasheed (NUST201200922) and Muhammad Arslan Mohsin (NUST201201342) Titled: Automatic Dishwashing Mashine be accepted in partial fulfillment of the requirements for the award of Bachelors of Engineering in Mechanical Engineering degree.

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Declaration

We certify that this research work titled Automatic Dishwashing Machine is our own work. The work has not been presented elsewhere for assessment. The material that has been used from other sources it has been properly acknowledged / referred.

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Dedicated to my parents

Acknowledgments

First of all I would thank ALLAH Almighty, who gave me knowledge and dedication to be able to complete this research.

Abstract

The first reports of a mechanical dishwashing device are of an **1850** patent in the United States by **Joel Houghton** for a hand-powered wood device. This device was made of wood and was cranked by hand while water sprayed onto the dishes. This device was both slow and unreliable. After that time a series of dishwashers were introduced by many companies. Then, after 1950's semi-automated Dishwasher Machines were introduced. By the 1970s dishwashers had become commonplace in domestic residences in North America and Western Europe. By 2012, over 75 percent of homes in the US and Germany had dishwashers.

These Dishwashers are fully equipped with latest technology and are fully automated, but they are mainly designed and being manufacture in Europe and USA, where utensils get stains of soft foods as compared to oily and masala's stains in Pakistan or Subcontinent region. That is the reason these dishwashers fail to proof their best efficiency in subcontinent region. Moreover, due to import of these sort of machineries, their prices go very high.

We designed and manufactured a dishwasher machine, which is designed for our culture, very cheap in price as compared to imported machines, most efficient and easy to use as compared to other dishwashers (which have usually a wash cycle time of minimum 35 minutes and required pre-rinsing or manual loading in racks).

Keywords:

Hand-Powered (Manual), Cracked (given a bend to), Pre-rinsing (Wash before putting them in machine), Subcontinent (Pakistan and India)

Table of Contents

List of Figures

List of Tables

Symbols

AL2024 T3	Aluminium Alloy 2024 heat treated
F	Load
t,t_1,t_2	Adherend thicknesses
t_a	Adhesive thickness
$\varepsilon,\varepsilon_{x1},\ \varepsilon_{x2}$	Longitudinal strains
τ	Shear stress
G	Modulus of rigidity of adhesive
E_1, E_2	Modulus of elasticity for plates
E_a	Modulus of elasticity for adhesive
l	Length of overlap
b	Width of overlap
A,B	Constants of solution of differential equation
τ_m	Mean tangential stress
$\tau_{n,}$	Destructive stress
M	Bending moment
E_{Total}	Total strain energy
σ	Tensile stress
$\sigma_{p(max)}$	Max peel stress
$d\Omega$	Structural domain

Chapter 1
Introduction

1.1 Background

In modern age, people don't want to wash the dirty utensils from their hand. In most of hospitals and restaurants, people prefer to get washed the utensils by some machine. Moreover, it is the need of the hour, where every task in our life is automated, so the process of washing dirty utensils should also be mechanized. Therefore, dishwasher machines were introduced. By 2012, over 75 percent of homes in the US and Germany had dishwashers.

And very few are aware of this technology in Pakistan. So, here is a huge gap in Pakistan's Market about this Automated Process Domestic Machine, which is needed to be filled.

1.2 Aim and Objectives

The aim of this project is to develop a machine which has following features:

- **Cheap in Price:** Normally dishwashers available in market are of minimum 70,000/- Rs. So it is out reach of a middle class family to afford a dishwasher.
- **Quality Wash:** In our Culture, utensils get hard stains of oils and masala's, using existing designed dishwashers for these type of utensils, they become unable to show their full efficiency. That's the reason, we should have to make a machine designed for our culture, which gives quality wash.
- **Low Consumption of Water:** We performed 20 experiments on 6 people family to determine the average consumption of water during the process of washing dishes at one time a day by a normal family of 6 persons. Our study and experimentation showed following results:

	Min. Water Flow Rate (Liter/min)	Min. Water Consumption (for 10 Minutes Process, Liters)	Max. Water Flow Rate (Liter/min)	Max. Water Consumption (for 10 Minutes Process, Liters)
For 1 Time a day	2.14	21.4	3.3	33.3
Per Day (3 Times)		64.2		99.9
Per Month		1926		2997
Per Year		**23,112**		**35,964**

Table 1.1: Survey on Water Consumption

This shows a terrible truth that, an average family of **six people** in Pakistan, wastes **25,000 liters** of Clean Water every Year, which is a huge amount. So, by automating this process, we would be able to save a huge amount of water.

- **Reduce the Wash Cycle Time:** Present Dishwashers have approx. 50 to 90 minutes wash cycle time, which is much time. Everybody wants to save his time, so in our design, we'll reduce wash cycle time of dishwashers machine too.

1.3 Research Methodology

The schematic of overall research methodology was consist of 4 major steps, which are following:

- Study of present Designs and Research Papers
- Preparing our Design and making CAD Models to analyze
- Fabrication of Machine
- Testing of Prototype and Improving the design

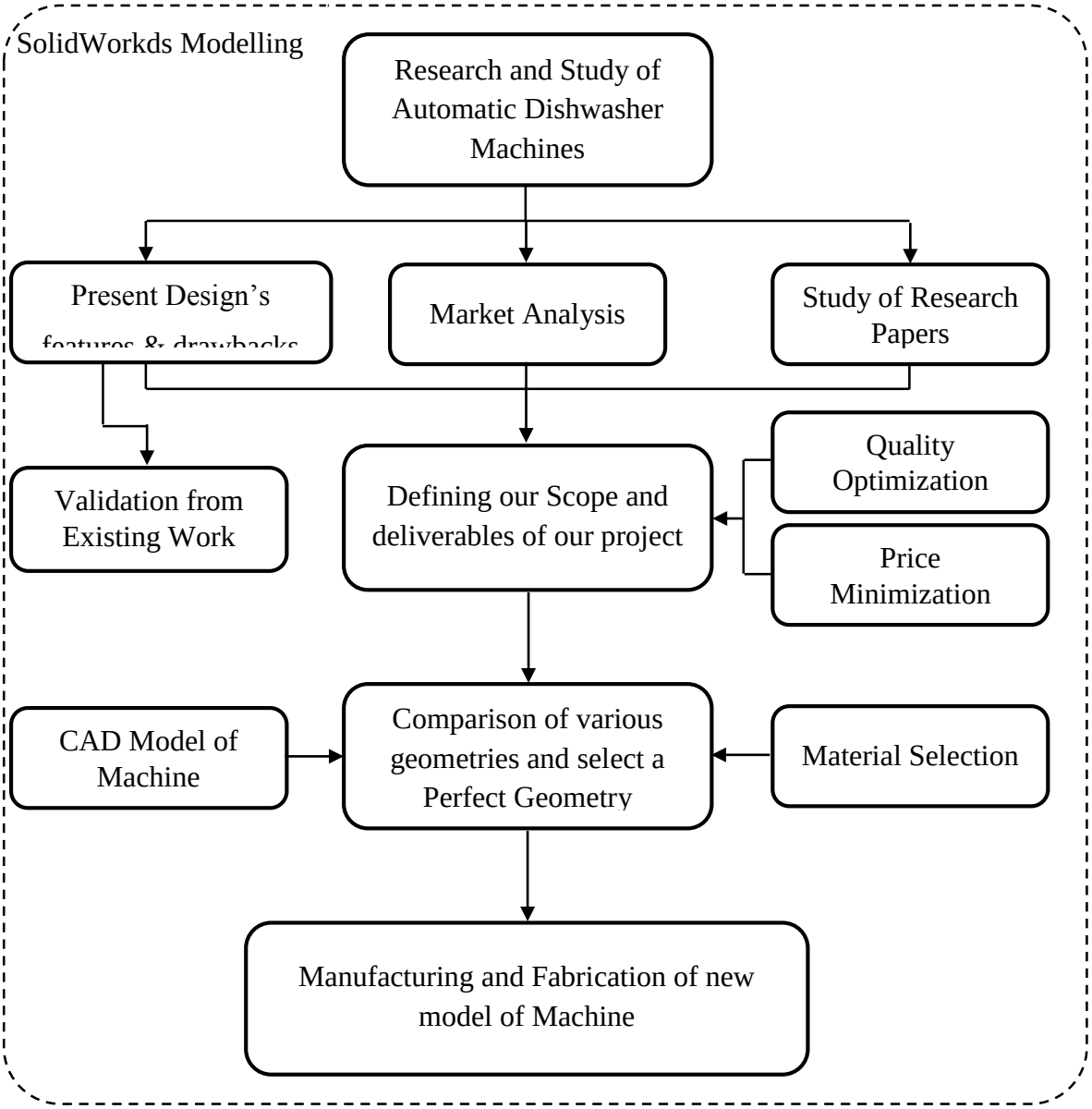


Figure 1.1: Overall Schematic of Research Methodology

1.4 Thesis Structure

The brief description of the contents of the remaining chapters in thesis is described below.

Chapter 2 Literature Review: Chapter provides a summary of the literature that has been reviewed and identified to be relevant to this research. This chapter also includes the methods to improve quality of washing utensils by different ways, on which research has been conducted up till now.

Chapter 3 Optimization of Working Process: This chapter is divided into two parts. First part consists of the individual part's working and second part consists on overall process of machine. The process of overall working as well as of individual parts is explained through diagrams and flow charts.

Chapter 4 Results and : The results of the optimization is given in this chapter. Also the comparison of base and optimized geometries for washing process has been discussed in this chapter.

Chapter 5 Conclusions and Future Work: This chapter presents the conclusion of the conducted research along with the proposed future work.

Chapter 2

Literature Review

2.1 Instruction Manuals of Dishwashers:

The study of instruction manuals of present dishwashers helped us a lot to determine the specification and technical aspects of machine. The following table shows the summary of technical aspects of different present dishwashers.

Energy and water consumption of some of dishwasher manufacturers and their models.

Brand	Model	Size	kWh/ Year	Gallons/ Cycle	Energy Factor (EF)	Federal Standard (EF)
AEG-Electrolux	F45078I-M	Standard	320	4.12	0.67	0.46
AEG-Electrolux	F65478VI-S	Standard	316	4.35	0.68	0.46
Ariston	L63*	Standard	270	5	0.80	0.46
Bosch	SHE42L1#UC	Standard	315	2.89	0.68	0.46
Bosch	SHE68E05UC	Standard	180	1.57	1.23	0.46
Bosch	SHE98M05UC	Standard	190	2.05	1.13	0.46
Frigidaire	DGHD2433	Standard	283	3.68	0.79	0.46
Gaggeneau	DF260760	Standard	180	1.57	1.23	0.46
GE	GDWT1**R	Standard	322	5.1	0.68	0.46
GE Profile	PDWT51*P10	Standard	322	5.5	0.72	0.46
General Electric	GHDA69*P	Standard	302	5.2	0.74	0.46
Ikea	IUD9750V	Standard	313	4	0.70	0.46
Kenmore	1310*K***	Standard	301	4.19	0.72	0.46
Kenmore	1332	Compact	174	2.7	1.30	0.62
Kuppersbusch	IGVS6607UL	Standard	234	2.21	0.92	0.46
LG	LDF993#**	Standard	285	3.4	0.76	0.46
LG Electronics	LDF692#**	Standard	285	3.4	0.76	0.46
Maytag	MDB8959AW**	Standard	291	4.15	0.75	0.46
Samsung	DMR78***	Standard	289	5.2	0.76	0.46
Siemens	SL65A703UC	Standard	290	2.58	0.74	0.46
Whirlpool	DP1040XTX**	Standard	296	3.96	0.73	0.46
Whirlpool	DU018DWT*	Standard	313	5.15	0.72	0.46

Table: 2.1: Energy Consumption of Some dishwashers

2.2 Research Papers on Dishwashers:

Research Paper study carried out by our team reveals a lot of information of technical aspects of machine. We came to know about the changes, which are going to be done in latest upcoming models of dishwashers. Their washing quality is being improved day by day. Some details of research papers are following which has been studied:

2.2.1 Application of Siemens S7 - 200 series PLC on Full-automatic Dishwasher:

According to the survey, 80% of China's population is currently busy working relationship because, more often choose the canteen, there are a considerable number of students in school meals in the study phase is also the canteen, so how effective the canteen clean dish became an important issue. The device based on Siemens S7-200 series PLC programmable controller, electric control of full-automatic dishwasher is designed and realized. This paper describes the hardware and software design of the system in detail, on-site application results demonstrate it is reliable and can be easily operated, while has a good performance and prospect of popularization.

2.2.2 Liquid automatic dishwashing detergents: A profile of toxicity:

The recent introduction of liquid automatic dishwashing detergents (LADDs) has resulted in numerous calls to poison information centers and, subsequently, a large number of referrals to emergency departments. As with their traditional granular counterparts, LADDs contain alkaline builders that contribute to the pH of these products. Exposure to granular automatic dishwashing detergents has been associated with caustic injury similar to the pathology produced by other alkaline corrosives. Do LADDs produce similar toxicity? There is no published information that profiles the toxic manifestations associated with exposure to LADDs. To determine their toxicity, all LADD exposures reported to a regional poison information center over a 12-month period were collected. One hundred ninety-two human exposure cases were reviewed. Pediatric patients accounted for 76% of the exposures; 76% were ingestions, 12% were dermal exposures, and

12% were ocular exposures. Seventy-nine percent of the patients were exposed to a full-strength product, and 21% contacted a dilute product or one that had already been through the dishwashing cycle. Of the patients who ingested a LADD, 91.1% remained asymptomatic, 8.2% had minor symptoms, and only one (0.7%) suffered moderate toxicity. In contrast, 91.3% of all patients who had an ocular exposure developed minor or moderate toxicity (73.9% vs 17.4%). Of dermal exposures, 69.6% were asymptomatic, and those with symptoms were the result of inappropriate use. Overall, 78.7% remained asymptomatic, 18.2% developed minor toxicity, and 3.1% developed moderate toxicity. Small oral and dermal exposures usually do not result in toxicity and do not necessitate referral to an ED. Ocular exposures are associated with a high incidence of at least minor toxicity and require ED evaluation.

2.2.3 A household dishwasher heated by a heat pump system using an energy storage unit with water as the heat source:

Electricity usage by a household dishwasher can be reduced by using a heat pump system to heat the dishwasher cabinet, dishware and washing water. The evaporator obtains the energy from an energy storage unit which consists of a container filled with water which freezes to ice. The majority of the heat transfer from the energy storage to the evaporator occurs when ice is created in the energy storage unit. A transient simulation model of a dishwasher with a heat pump system was developed and compared to an experimental setup with good agreement. A simulation study of the compressor cylinder volume and the compressor operating time was performed. The results showed a 24% reduction in total electricity use compared to a dishwasher cycle using a traditional electric element.

2.3 Outcome of Research Study:

As these designs are full of innovation, but still there are some drawbacks in these design. According to studying of Customers Reviews & Feedback and thorough study of engineering design of Dishwashers, some following drawbacks are highlighted:

- The main drawback of Modern Dishwashers is their prices, which is very high and make them out of the approach of a middle class family. In Pakistan, as dishwashers are not being manufacture locally, but are imported. So, their prices are very high. Price of dishwasher by some brand, like L.G, Samsung, Whirlpool and etc, starts from 80,000/- Rs. and goes up to 3,00,000/- Rs. Some dishwashers imported from China are also available starting from 40,000/- Rs. But in Pakistan, they are still out of range from a middle class family.

- The other main drawback of these dishwashers is that they are perfectly designed for American and European Culture, where dishes have not hard dirty stains. They don't work perfectly for South Asia Region (including Pakistan, India, Bangladesh and other countries) where utensils get hard stains of Masalas and Oils. We can wash these utensils in modern dishwashers by increasing cycle time, but it requires more water and energy and still don't wash perfectly.

- As, from the given data of two famous dishwashers, one can see that, these dishwashers still use enough water (average 20-24 liters per cycle) which is still very high amount and should be reduced to as minimum as possible.

- Another main drawback of these designs is the long cycle time of washing dishware. Average time of a cycle from given data is 90-120 minutes, which is very high. In modern era, time is very precious wealth. If you have some gathering at your home, and you need dishes to be washed quickly, then you should have to wait minimum for an hour, which nobody can do.

- Another main drawback is in its Engineering Design. For washing your dishware, you have to load your dishes in racks and then after washing, you have to unload them, which require 20-30 minutes of human effort. As, people don't want to do this with dirty utensils so, this thing should be eliminated and design should be such that, it will not require human effort to load or unload the dishware.

- Racks and Shelves are not flexible and user friendly. You have to follow a certain procedure to use them, which makes its usage complex.

- Heating process of water, for rinsing is also very large energy consumer (with average usage of 1.5 KWh). As, hot water from drainage tub is hot enough. So, it can be use in heat exchanger, to hot incoming cold water, which would reduce the energy consumption of overall process.

Chapter 3
Optimization of Working Process

3.1 Introduction

In the light of above mentioned drawbacks, we made a suitable design for our culture, where utensils have hard stains of masalas and are oily also. The optimization of present designs to a new model, which fulfill all the demands of customer has been necessary for our society. This has been done by removing rack system and introducing conveyer belt system instead of. So, the overall working of new model of dishwasher has been described below after the description of complete individual parts / components of machine.

3.2 Components of Machine

The machine have simple geometry, consists of two arms for conveyer belt. From right side, dirty utensils will be entered to the machine inertly and they will come out from left side. Four following procedures will be done on utensils inside the machine.

- Washing with Detergent mixture water
- Washing with clean water
- Drying with heat blower
- Disinfected through UV light

All these processes are carried out inside the machine. Machine consists of two chambers, one is for washing, and other is for controls, which controls washing process, i.e.; Boiler, water mixer, solenoid valves, microcontrollers and etc. Details of these components is following:

3.2.1 Solenoid Valve:

A solenoid valve is an electromechanically operated Valve. The valve is controlled by an electric current through a solenoid: in the case of a two-port valve the flow is switched on or off; in the case of a three-port valve, the outflow is switched between the two outlet ports.

Figure: 3.2.1 Solenoid valve

3.2.2 Water Heater:

A hot water container is used for the purpose of water container heater. It heats the water up to 70^0 C or 40^0 C, on demand of user, who selects the option of hot water wash or cold water wash. It contains a temperature sensor, LM35, which controls the thermocouple of heating element.

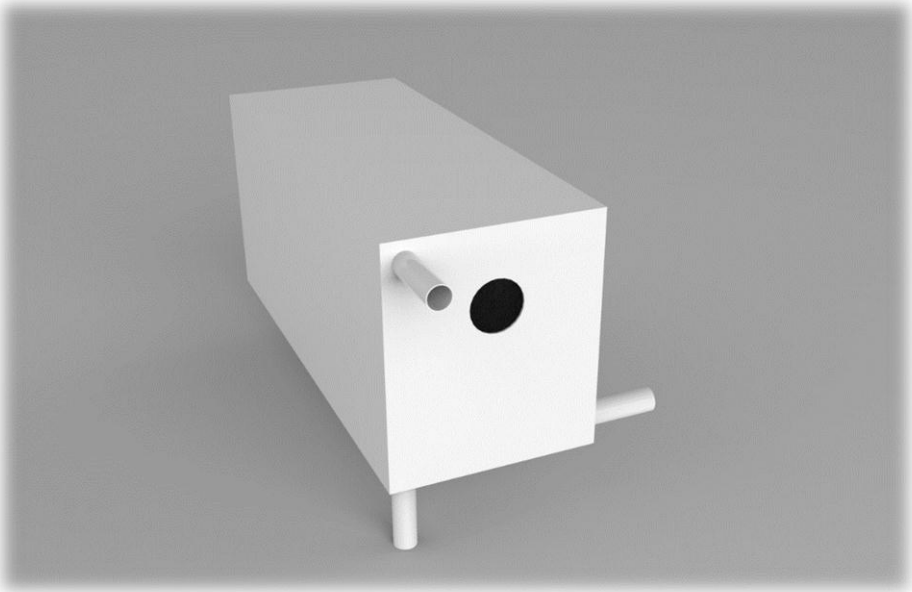


Figure: 3.2.2a Water container / heater

The heating element for the heating purpose is of 12 kW capacity and is shown below with temperature sensor:

Fig: 3.2.2b Heating Element and LM35 temperature sensor

3.2.3 Conveyer Belt:

Small strips of conveyer belts are used in our designed machine, which will carry dirty utensils. Strips are used for the purpose that the utensils get washed from both sides, i.e. from upside as well as from down side water showers too to get better quality wash.

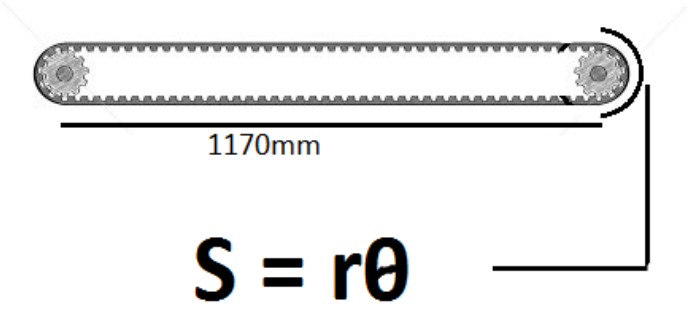
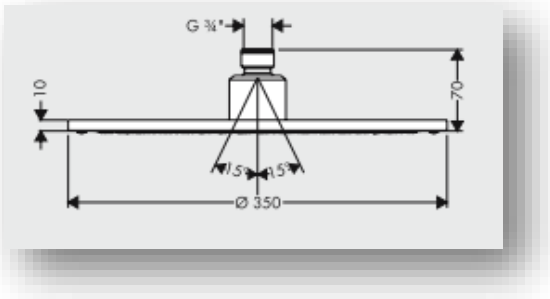


Figure: 3.2.3 Conveyer belt length and diagram

3.2.4 Water Showers:

There are total four water showers in our design. Two are on the top side, and other two are at the bottom. 1st up and down showers are for spraying water and detergent mixture on the utensils, from both up and down direction. And other two are for clean water spray on utensils from up and down side.



Firgure: 3.2.4a Water shower

The properties of these shower heads are shown in following graphs:

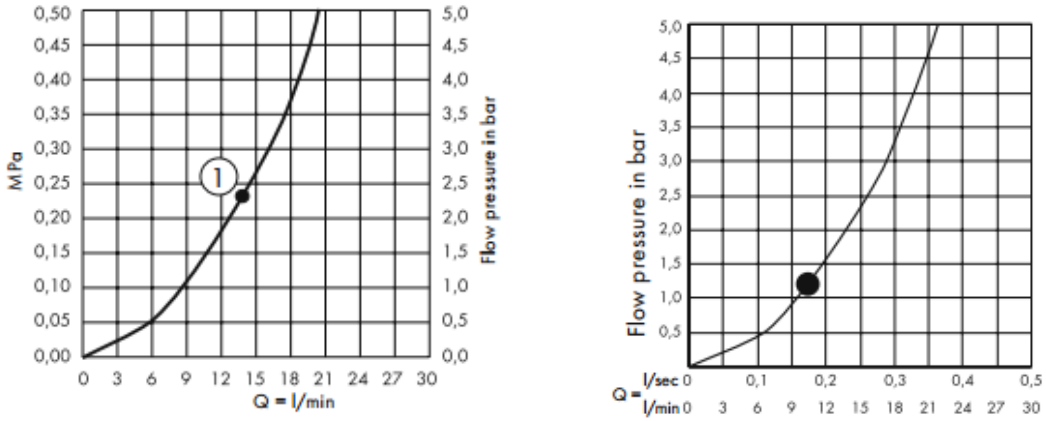


Figure: 3.2.4b Graph for flow rate and pressure in water showers

These water showers were not exact of our demanded or designed flow rate, but they were the only one available in market nearest to our required flow rate and pressure. The quality of wash can be improved more by putting water showers of high jet and low flow rate.

3.2.5 DC Water Pumps:

Two submersible water pumps of 12V DC source have been used in this machine to make pressurized flow of water in water showers and are installed inside the both water containers, i.e. inside hot water container, for clean water supply to 2nd up and down showers and in mixing chamber to supply mixture of water and detergent to 1st up and down side water showers.

Figure 3.2.5: DC Water Pumps

Same as water showers, pumps are also most critical part of this machine to be chosen. Calculated flow rate and head pressure were optimized, but the installed pumps are nearest available pumps to our values. The quality of wash can be improve more by using pump of high head, low power and flow rate.

3.2.6 Main frame of Machine:

Main body of machine is designed in such a way that, it'll make a user friendly design. It has two arms as mentioned, on left and right sides. These are to be adjusted on shelf of machine. The overall dimensions and size of machine is nearest possible to standard machines, which is also shown in figure below:

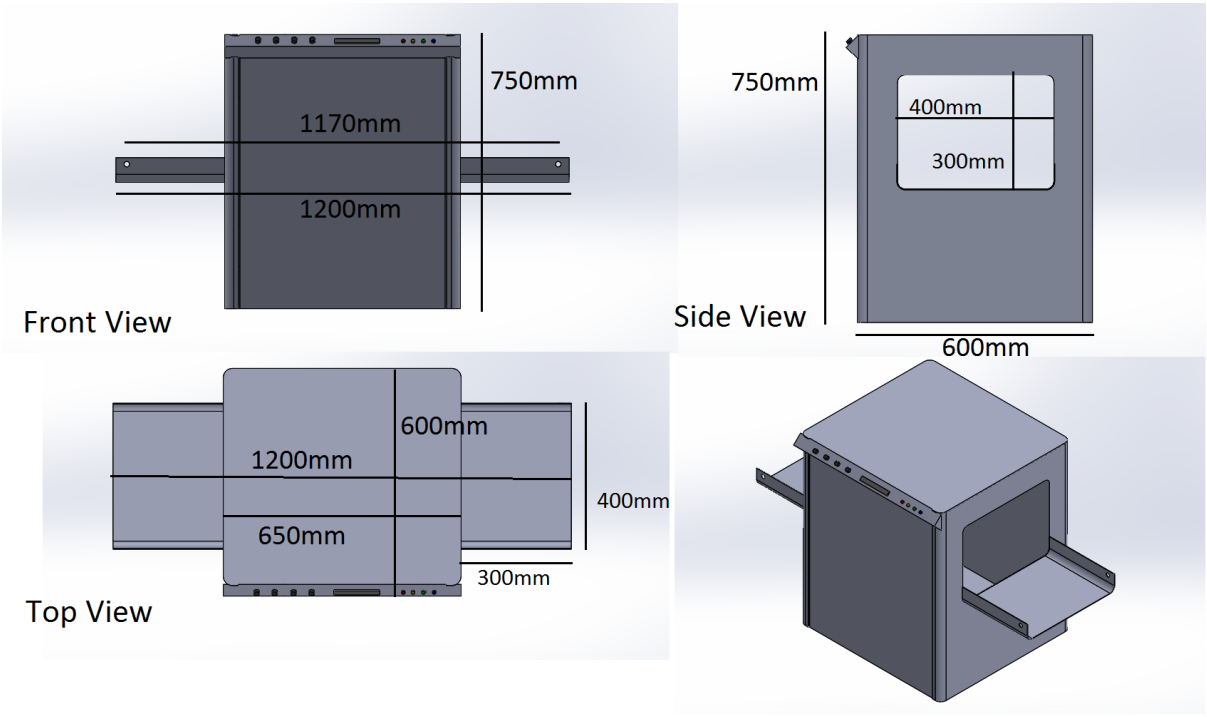


Figure: 3.2.6 Main frame (body) of machine

3.2.7 Electronic Circuits of Machine:

The programming of machine is done using Arduino Mega, and AC controlled devices are controlled on DC signals by using Relay Modules of 5V. Both Arduino and Relay modules are shown in following figure:

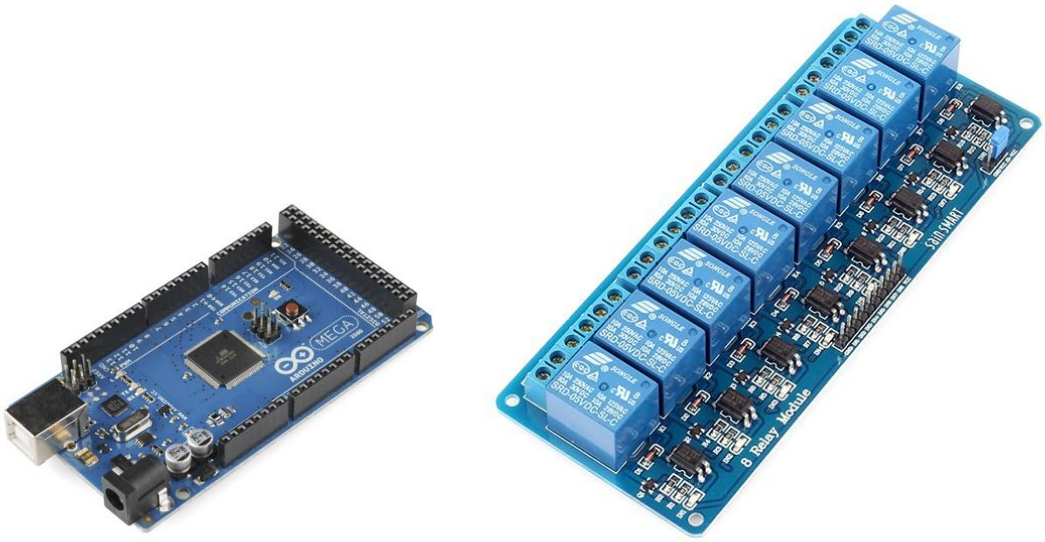


Figure 3.2.7: Arduino Mega 2650 and Relay Module

3.3 Working of Whole Machine:

The side views of main frame of machine are shown in Figure 3.3a and Figure 3.3b:

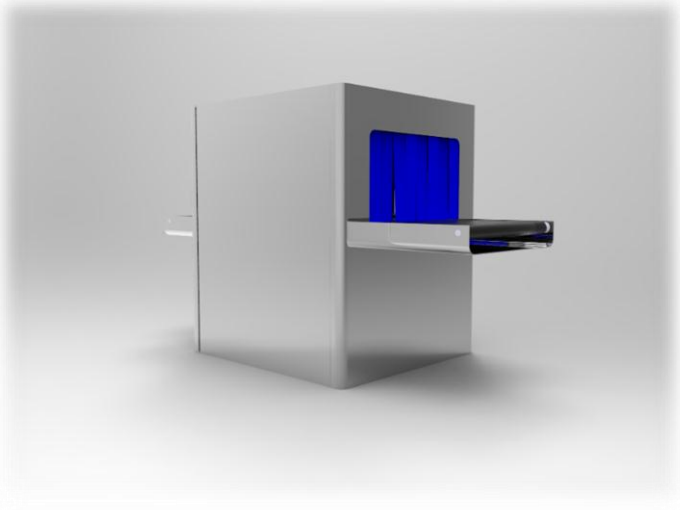


Figure 3.3a: Back and Side view of Machine

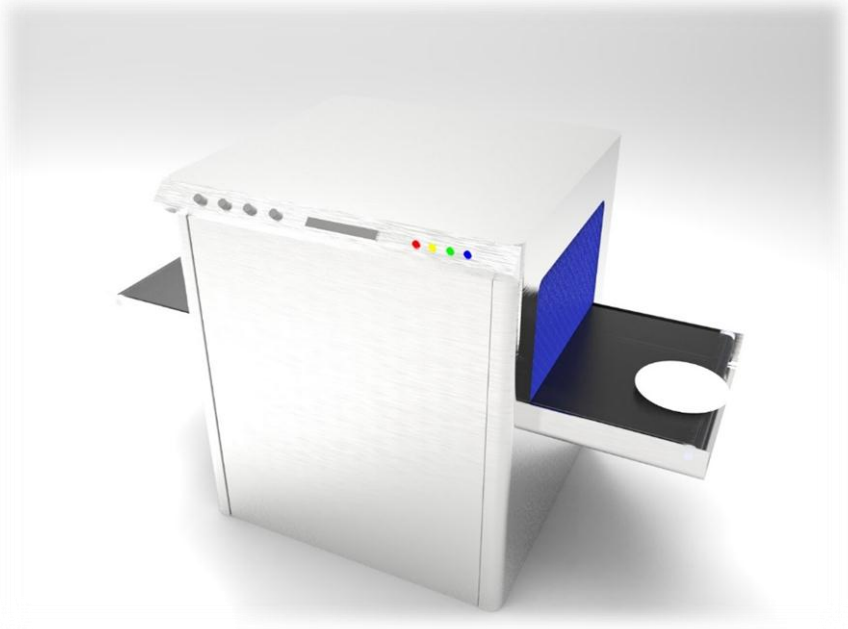


Figure 3.3b: Front and Top View of Machine

3.4 Arduino Codes for Programming of Machine:

Arduino Codes for the programming of machine have been shown below:

```
/*
Total 12 Variables.
1. Input Valve
2. Water Level Sensor
3. Temperature Sensor
4. Heating Rod
5. Valve connected to next section
6. Motor for Hot Water
7. Motor inside Mixing Section
8. Motor outside mixing section
9. DC motor for conveyer belt
10. Hot Air Blower Element
11. UV lights
12. Start Switch
*/
int Water_Level_Sensor= A0;    // select the input pin for the water level sensor.
int Temperature_Sensor= A1;    // select the input pin for the Temperature sensor.
int Input_Valve = 5;          // select the pin for on/off of Input Valve.
int Heating_Rod = 6;          // select the pin for on/off of Heating Rod.
int Valve_Connected_To_Next_Section= 7;  // select the pin for on/off of Valve connected to next section.
int Motor_For_Hot_Water= 8;    // select the pin for on/off of Motor of Hot water
int Motor_Inside_Mixing_Section= 9; // select the pin for on/off of Motor_inside_Mixing_Section
int Motor_Outside_Mixing_Section= 10;
int DC_Motor_For_Conveyer_Belt= 11;
int Hot_Air_Blower_Element= 12;
int UV_Lights= 13;
int Start_Switch =14;
int water_level= 0;
int heat_level= 0;
int start_switch= 0;
void setup() {
```

```
 // declare the ledPin as an OUTPUT:
 pinMode(Input_Valve, OUTPUT);
  pinMode(Heating_Rod, OUTPUT);
  pinMode(Valve_Connected_To_Next_Section, OUTPUT);  pinMode(Motor_For_Hot_Water, OUTPUT);


 pinMode(Motor_Inside_Mixing_Section, OUTPUT); pinMode(Motor_Outside_Mixing_Section, OUTPUT);
pinMode(DC_Motor_For_Conveyer_Belt, OUTPUT);
pinMode(Hot_Air_Blower_Element, OUTPUT);
pinMode(UV_Lights, OUTPUT);
  // initialize serial communication at 9600 bits per second:
Serial.begin(9600);
pinMode(Start_Switch, INPUT);


}
void loop()
{
// Delay before the start of system.
delay(2000);
 start_switch= 1;
  // program stats with condition loop if switch is on, otherwise program does not run.
  if (start_switch != 1)
  {
    digitalWrite(Valve_Connected_To_Next_Section, LOW);
    digitalWrite(Hot_Air_Blower_Element, LOW);
    digitalWrite(UV_Lights, LOW);
    digitalWrite(Motor_For_Hot_Water, LOW);
    digitalWrite(Motor_Inside_Mixing_Section, LOW);
    digitalWrite(Motor_Outside_Mixing_Section, LOW);
    digitalWrite(Input_Valve, LOW);
    digitalWrite(Heating_Rod, LOW);
    delay (7000);
    start_switch=1;
  }
  if (start_switch == 1)
```

```
 {
// Reading the value from Water level sensor and Temperature Sensor:
   water_level = analogRead(Water_Level_Sensor);
   heat_level = analogRead(Temperature_Sensor);
   Serial.println(water_level);
   Serial.println(heat_level);
   delay(2000);
   if (water_level > 50 && heat_level > 50)
   {
    delay(10000);
    digitalWrite(Input_Valve, HIGH);
    digitalWrite(Heating_Rod, HIGH);
 delay(10000);
    // turn on the Valve Connected To Next Section
    digitalWrite(Valve_Connected_To_Next_Section, HIGH);
    // turn on the Motor inside Mixing Section     digitalWrite(Motor_Inside_Mixing_Section, HIGH);
// Delay of 10 seconds
    delay (10000);
    // turn on the DC_Motor For Conveyer Belt
    digitalWrite(DC_Motor_For_Conveyer_Belt, HIGH);
    delay(10000);
    // turn on the Motor outside Mixing Section
    digitalWrite(Motor_Outside_Mixing_Section, HIGH);
    // turn 0on the Motor For Hot Water
    digitalWrite(Motor_For_Hot_Water, HIGH);
  delay(10000);
    // turn on the UV lights
    digitalWrite(UV_Lights, HIGH);
    // turn on the Hot Air Blower Element
    digitalWrite(Hot_Air_Blower_Element, HIGH);
    delay (5000);
 if (water_level < 50 || heat_level < 50)
   {
    digitalWrite(Valve_Connected_To_Next_Section, LOW);
```

```
      digitalWrite(Hot_Air_Blower_Element, LOW);



digitalWrite(UV_Lights, LOW);
      digitalWrite(Motor_For_Hot_Water, LOW);
      digitalWrite(DC_Motor_For_Conveyer_Belt, LOW);
      digitalWrite(Motor_Outside_Mixing_Section, LOW);
      digitalWrite(Motor_Inside_Mixing_Section, LOW);
      delay(3000);
    }
  }
  }
}
```

3.5 Flow Chart of Overall Working Process:

The overall working cycle of machine can be understood by following flow chart:

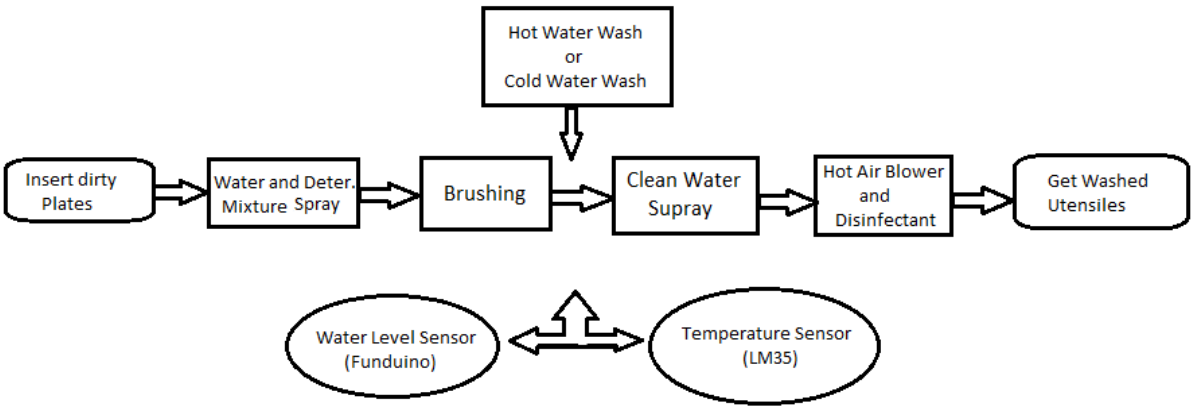


Figure 3.5: Flow Chart of working of Machine

Chapter 4

Results and Discussions

4.1 Case I: Normal Water:

When user wants to get washed utensils from normal water, i.e. without heating water, then the results are following:

Flow rate	1.4 lit/min
Temperature of Water	25^0 C
Power Consumption	0.7 kWh
Wash Cycle Time	7-10 minutes

Table 4.1: Results for using normal water

4.2 Case II: Hot Water:

When user selects the option of hot water wash, then programming loop for hot water operates, which controls the heating element's temperature to almost 70^0 C, then make its mixture. Machine doesn't do any work, until the required temperature is not achieved. The results of machine for hot water washed utensils are following:

Flow rate	1.4 lit/min
Temperature of Water	70^0 C
Power Consumption	1.4 kWh
Wash Cycle Time	12-15 minutes

Table 4.2: Results for using hot water

4.3 Discussions:

The results show that the machine consumes more power for heating water, and it also takes more time to heat the water, this is the reason wash cycle time for hot water is higher than of normal water wash cycle. Moreover, during the process, if temperature drops too much from the required temperature, due to new addition of cold water, then the machine stops working until it reaches to its required temperature.

Chapter 5
Conclusions and Future Work

5.1 Conclusions:

In this project, we got excellent results for optimizing designs of dishwashers. The new design seems to be more user friendly if it would undergoes some more work after experimentations. Some recommendations are given in future work, which would be helpful for those who want to make it a complete domestic product.

5.2 Future Work:

1. The Collaboration of water level sensor (Funduino) and temperature sensor (LM35) is not optimized yet. It requires more time and more experimentations to be done to optimize their mutual function to maintain both level as well as temperature of water at required level.

2. In future, if we need to get more quality wash, then we should have to install water jets of exactly calculated values. Currently installed water showers don't form sharp jets and consumes more water. It requires more budget and time to be completed.

3. There is a lot of work to be done on collaboration of timings of mechanical components, i.e. conveyer belt, pumps, electric heater and switches, as if we use machine continually for more time, its system collapse and needs to be restarted.

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