American Scientific Research Journal for Engineering, Technology, and Sciences (ASRJETS)

ISSN (Print) 2313-4410, ISSN (Online) 2313-4402

http://asrjetsjournal.org/

Design of a Special Purpose Dish Washing Machine

Igoke Major[a*], Valentine Zorta[b]

[a,b]*Department of Mechanical Engineering, Faculty of Engineering, University of Port Harcourt, Nigeria*

[a]*Email: igoke.major@uniport.edu.ng*

[b]*Email: morphytech@yahoo.com*

Abstract

This work is based on the design of a special purpose dish washing machine. Its special purpose lies in the fact that it handles only dishes made of ceramics. The machine is designed to use electrical energy for heating water and to produce rotation of the spray arm which project hot water unto the dishes. The principle on which the dish washing machine is designed is based on the fact that the pressure and water temperature of water jets required to produce scouring and softening effect on dirt and easily remove them is about 300kPa and 45^{o}C respectively. The force of the water jet impacting unto the dishes is taken into account in the design and the pressure due to the force exerted by the water jet produced, is negligible compared to both the tensile strength (1138 MPa) and compressive strength (2400 MPa) of the ceramic (Alumina Porcelain) or any other ceramic, and hence cannot break any of the ceramic dishes. The machine is designed to be fitted with a water heater, electric motor and a water pump of power rating 2.2KW, 0.25KW and 0.5KW respectively. The fabricated design of this special purpose dish washing machine will handle 20 dishes in a batch process and complete a wash cycle in a minimum of seven (7) minutes.

Keywords**:** dishwasher; heat exchanger; washing; index.

1. Introduction

A dishwasher is a mechanical device for washing and cleaning dishes and eating/cooking utensils. Dishwashers can be found in restaurants and homes. The practice of dish washing is as old as man. Every natural man knows by intuition that he needs to wash what he had used if he must use it again. Locally, dishes are washed by hand by scrubbing them and immersing them in a rinse of plain water. Silverware is washed by placing loose silverware in a tray, washing them several times, while dishes made of plastics are usually more difficult to clean when it comes in contact with greasy and oily meals.

----

* Corresponding author.

Before the advent of mechanical washers, a family's home washing was done in a wooden or galvanized tub being rubbed on a corrugated washboard to force the water through and the dirt out. Then the wash was put through a wringer to squeeze out the excess water and family hung on a line to dry. There are cultural divisions over rinsing and drying after washing [1]. The area where dishes are washed, particularly in food services is sometimes called a "dish-pit" and people that wash dishes are variously known as Pan Diver, Kitchen Porters or Kitchen Police [2]. The first mechanical dishwashing machine was reported in the United States of America in 1850. It was design and constructed by Joel Houghton for a hand-powered good device [1]. This device was made of wood and was cranked by hand while water sprayed onto the dishes. Alexander L.A. was granted another patent in 1865 for constructing a dishwasher that was similar to the first but featured a hand-cranked rack system. According to the report of [3], two models of dishwasher were manufactured in 1995 – the Conventional Model and the Adaptive Control. Model. The Conventional dishwasher model was manufactured in January 1995 and it has five cycle settings namely Rinse, Short, Light, Normal and Heavy. Three special options are available for each setting – (1) high temperature rinse (2) high temperature wash and (3) truncated cycle which involves deactivating the heating element in drying stage. Water consumption in this dishwasher model is controlled by a float control device.

In recent times, researchers have paid attention to the design and fabrication/development of dish washing machines. In [4], is presented the design and development of semi-automatic dishwasher, while [5] presented the design and fabrication of semi-automatic dish and utensil washing machine. Both machines were fabricated and results obtained from performance test of these machines showed that they are efficient compared to manual washing. Some other researchers have focused on factors that affect dish washing, for example, investigating the insufficient cleaning of dirty dishes in confined living spaces and the design of a highly marketable dishwasher solution was presented by [6], while other researchers have studied the energy utilization of modern dish washers, for example, [7] studied how energy efficient are modern dishwashers. This present study, therefore presents a detailed design of a special purpose dish machine for dishes made of ceramics only, which modern dishwashers fabrications should adopt.

1.2 Standard dishwasher

The international standard for the capacity of a dishwasher is expressed as standard place settings. Dishes or plates of irregular sizes may not fit properly in a dishwasher's cleaning compartment, so it is advisable to check for compatibility before buying a dishwasher. [8], has provided standards for the design of residential dishwashers. According to [9], the "table setting capacity" of the household electric dishwasher is the number of place settings and serving pieces that may be placed in a dishwasher. Most Common residential dishwashers load between 15 and 22 Place Settings. By Installation, [9] classified dishwashers into four, namely:

1) **Built-in:** A built-in dishwasher is a dishwasher which is permanently connected to the household water supply lines and may be installed to the electrical supply either permanently or with a power cord.
2) **Portable:** A portable dishwasher is a dishwasher which is not permanently connected to the household water and electric supply lines. It can be mounted on wheels and easily moved from one place to another in normal use.

3) **Convertible:** A convertible dishwasher is a portable dishwasher which has been specifically designed so that, with modifications, it may be "converted" or changed readily to be permanently installed, placed and used as any other built-in dishwasher.
4) **Free-Standing.** A free-standing dishwasher is a dishwasher of the built-in or convertible type provided with a top and side enclosure, installed as a free-standing unit instead of under the kitchen work surface or countertop, and may or may not be permanently connected to the household water and electric supply.

Commercial dishwashers are rated as plates per hour. The rating is based on standard sized plates of the same size. Dishwashers that are installed into standard kitchen cabinets have a standard width and depth of 60 cm, and most dishwashers must be installed into a hole a minimum of 86 cm tall. Portable dishwashers exist in 45 and 60 cm widths, with casters and attached countertops.

Present-day dishwashing machines feature a drop-down front panel door, allowing access to the interior, which usually contains two or sometimes three pull-out racks (baskets). A drawer dishwasher, first introduced by Fisher and Paykel in 1997, is a variant of the dishwasher in which the baskets slide out with the door in the same manner as a drawer filing cabinet, with each drawer in a double-drawer model being able to operate independently of each other [10].

The inside of a dishwasher must either stainless steel or plastic in accordance to the requirement of [11]. Stainless steel tubs resist hard water, provide better sound damping, and preserve heat to dry dishes faster. Many new dishwashers feature microprocessor-controlled, sensor-assisted wash cycles that adjust the wash duration to the quantity of dirty dishes (sensed by changes in water temperature) or the amount of dirt in the rinse water (sensed chemically/optically). This can save water and energy if the user runs a partial load. In such dishwashers the electromechanical rotary switch often used to control the washing cycle is replaced by a microprocessor but most sensors and valves are still required to be present. However, pressure switches (some dishwashers use a pressure switch and flow meter) are not required in most microprocessor controlled dishwashers as they use the motor and sometimes a rotational position sensor to sense the resistance of water, when it senses there is no cavitation it knows it has the optimal amount of water. A bimetal switch or wax motor opens the detergent door during the wash cycle.

2. Materials and Methods

The mechanical dishwasher cleans by spraying hot water, typically between 55 and 75 °C (130 and 170 °F) at the dishes, with lower temperatures used for delicate items. A mix of water and detergent is circulated by a pump. Water is pumped to one or more rotating sprays arms, which blast the dishes with the cleaning mixture. Once the wash is finished, the water is drained, more hot water is pumped in and a rinse cycle begins. After the rinse cycle finishes and the water is drained, a heating element in the bottom of the tub heats the air to dry the dishes.

2.1 Design Bases

The design is based on the fact that the dishwasher will undergo a complete wash cycle in 5.0 minutes, washing at least 20 ceramic dishes. The sprayed water pressure was chosen base on the standard of American National Standard Institute (ANSI) on dishwasher construction [11].

2.2 Basic Components

The basic components of the dishwasher are:

1. Spray arm,
2. Spray supply pipe (Pipe1),
3. High pressure pipe (Pipe2),
4. Heat exchanger,
5. Water pump, and
6. Electric motor

The flow diagram for dishwasher is shown in Figure 1 below.

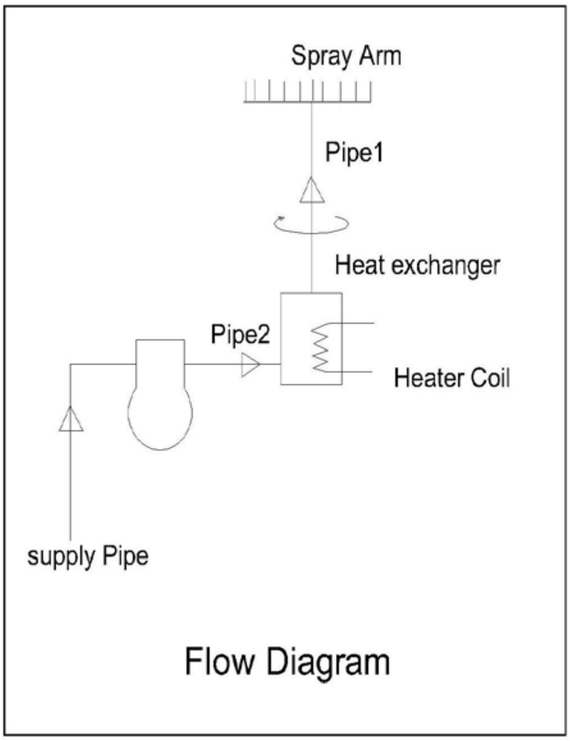

Figure 1: flow diagram of dishwasher

1. **Spray arm:** The spray has ten spray nozzles through which the high-pressured water escape to the plates (dishes) the spray supply water with sufficient pressure which blast on the dishes causing stain removal action. The spray is rotated by a small electric motor connected to the pipe 1 by belt and pulley.

2. **Spray Supply Pipe (Pipe 1):** this pipe is made of steel and it is directly connect the heat exchanger to the

spray. It attached to the heat exchanger and the top. Bars by special bearings which allow free rotation on its stem is attached a speed reduction pulley connected by belt to the electric motor.

3. **High Pressure Pipe (Pipe 2):** This pipe connects the pump to the heat exchanger. It carries cold water. It is made of strong plastic.

4. **Heat Exchanger:** The heat exchanger is made of steel cylinder with heating coil inside. Cold water from the pump enters the cylinder, get heated by the oil and discharge through pipe 1 to the spray.

5. **Water Pump:** This pump provides pressure and speed to the supply water and supply it to the exchanger.

6. **Electric Motor:** The motor is a compressed type and has the function of rotating the pipe 1 thereby rotating the spray

2.3 Components design

The essence of this design is to determine the right sizes and materials of the components as this will prevents sudden failure of the components. Design relations for various machine components is found in [12, 13].

2.3.1 Determination of spray discharge velocity (V_d)

The spray discharge velocity is determine using equation (1) given by:

$$V_d = \sqrt{2gh} \qquad (1)$$

Where:

g = acceleration due to gravity [m/s^2], and

h= height of sprayed water required for complete washing [m].

The sprayed water must attain a sufficient height such that all the parts of the dishes have sufficient water pressure for effective and complete washing.

2.3.2 Spray supply pipe diameter (d_1)

Discharge from each spray nozzle is given by equation (2) as:

$$Q_n = A_n V_d \tag{2}$$

but the cross-sectional area of the nozzle is given by equation (3) as:

$$A_n = \frac{\pi d_n^2}{4} \tag{3}$$

hence the discharge from each spray nozzle is obtained from equation (4):

$$Q_n = \frac{\pi d_n^2 V_d}{4} \tag{4}$$

Where:

Q_n = discharge from each spray nozzle [m^3/s]

d_n= spray nozzle diameter [m]

V_d = discharge water velocity [m/s]

The total discharge from spray arm is obtained using equation (5):

$$Q_s = nQ_n \tag{5}$$

Where:

Q_s= total discharge from spray arm [m^3/s]

n = number of spray nozzles [-].

Let η_1 = efficiency of water delivery from pipe 1 to the spray arm, then the total discharge from spray arm is expressed in equation (6a) as:

$$Q_s = \eta_1 Q_1 \tag{6a}$$

From which the volumetric flow rate in pipe 1, Q_1 is expressed in equation (6b) as:

$$Q_1 = \frac{Q_s}{\eta_1} \qquad (6b)$$

The efficiency η_1 account for water losses in the joint where the spray arm is join to pipe1.

Substituting equation (5) into equation (6b), the volumetric flow rate in pipe 1, Q_1 can also be expressed as shown in equation (7),

$$Q_1 = \frac{n\,\pi\, d_n^2 V_d}{4\,\eta_1} \qquad (7)$$

also, the flow rate in Pipe1 can be obtained using equation (8) given as:

$$Q_1 = \frac{\pi\, d_1^2 V_1}{4} \qquad (8)$$

from which the diameter of pipe 1 is obtained using equation 9:

$$d_1 = \sqrt{\frac{4\,Q_1}{\pi\, V_1}} \qquad (9)$$

Where:

V_1 = Velocity of water flow in pipe 1 [m/s].

The velocity of water flow in pipe 1 is determined using Bernoulli's Equation as expressed by equation (10):

$$V_1^2 = \frac{2}{\rho}\ (P_s - P_1) + V_d^2 + 2g\,(Z_s - Z_1) \qquad (10)$$

Where:

$P_S - P_1 = \Delta P$ = Pressure drop in the spray arm [Pa].

ρ = density of water [kg/m^3]

Pressure drop is due to sudden Enlargement into the spray arm and is given by equation (11) as:

$$h_e = \frac{(V_{1u} - V_{1d})^2}{2g} \qquad (11)$$

Where:

V_{1u} = upstream velocity of flow in pipe 1 [m/s], and

V_{1d} = downstream velocity of flow in pipe 1 [m/s].

Water pressure varies with depth according to equation (12);

$$\Delta P = pg\,\Delta h \qquad (12)$$

Combining equations (9), (10) and (11) yields an expression for V_1 and expressed by equation (13);

$$V_1 = \sqrt{\frac{V_d^2 + 2g\,(z_s - z_1)}{1.5} + h_e} \qquad (13)$$

V_1 was evaluated from equation (13) and substituted into equation (9) to determine the diameter of pipe 1. The closest standard pipe is selected for the fabrication.

2.3.3 Pressure pipe diameter (d_2)

The diameter of pressure pipe was determined as follows:

1. Pressure drop by sudden expansion in the heat exchanger is given by equation (14):

$$h_s = \frac{(V_{2u} - V_{2d})^2}{2g} \qquad (14)$$

Where:

V_{2u} = upstream velocity of flow in pipe 2 [m/s], and

V_{2d} = downstream velocity of flow in pipe 2 [m/s].

Pressured drop by sudden contraction into pipe 1 from the heat exchanger is given by equation (15):

$$\Delta P_{b1} = 0.5 \frac{V_1^2}{2g} \qquad (15)$$

2. Velocity of flow in the heat exchanger (V_b) was determine as follows:

The flowrate in pipe 2 is expressed as given in equation (16);

$$Q_b = \frac{1}{\eta_2} Q_1 \qquad (16)$$

Where η_2 = Efficiency of water flow from pipe 2 to pipe 1.

η_2 account for water leakage in the special bearing at the exit of the heat exchanger.

From equation (16), the cross-sectional area of the heat exchanger, A_b is given by equation (17a);

$$A_b = \frac{1}{\eta_2} A_1 V_1 \qquad (17a)$$

From which the flow velocity, V_b in the heat exchanger is obtained as expressed in equation (17b);

$$V_b = \frac{A_1 V_1}{\eta_2 A_b} \qquad (17b)$$

Substituting equation (17c) into equation (17b) yields equation (18), which is another expression of the flow velocity, V_b in the heat exchanger. The cross-sectional area, A of a circular pipe of diameter, d is expressed as:

$$A = \frac{\pi d^2}{4} \qquad (17c)$$

Hence, the flow velocity, V_b in the heat exchanger is then expressed as shown by equation (18).

$$V_b = \frac{{d_1}^2 V_1}{\eta_2 d_b^2} \qquad (18)$$

Where:

V_b = velocity of water flow in the heat exchanger [m/s], and

d_b= diameter of heat exchanger pipe [m].

Substituting equation (18) into equation (15) yields equation (19):

$$\Delta P_{b1} = \frac{\rho V_1^2}{2}\left(1 - \frac{d_1^4}{\eta_2^2 d_b^4}\right) \qquad (19)$$

Total pressure losses in the heat exchanger is expressed by equation (20),

$$\Delta P_b = \Delta P_{b1} + \Delta P_{2b} \qquad (20)$$

or as shown in equation (21).

$$\Delta P_b = \frac{\rho V_1^2}{2}\left(1 - \frac{d_1^4}{\eta_2^2 d_b^4}\right) + \frac{0.5\,\rho V_2^2}{2} \qquad (21)$$

From Bernoulli's equation, we have that the velocity of flow in pipe 2 can be expressed as shown in equation (22);

$$V_2^2 = {}^2/_\rho \, (-\Delta P_b) + V_1^2 + 2g\,(Z_1 - Z_2) \qquad (22)$$

Combining equations (21) and (22) gives us equation (23):

$$V_2^2 = \frac{2V_1^2\, d_1^4}{3\eta_2^2\, d_b^4} + \frac{4g}{3}(Z_1 - Z_2) \qquad (23)$$

Where:

Z_1 = Height pipe 1 above the horizontal ground [m], and

Z_2 = Height of pipe 2 above the ground [m].

From equation (16), the diameter of pipe 2 is given by equation (24) as:

$$d_2 = \sqrt{\frac{4\,Q_1}{\eta_2 \pi\, V_2}} \qquad (24)$$

V_2 is obtained using equation (23).

2.3.4 Force Exerted on the dish by the water jet

The force exerted on a moving dish which is normal to the water jet is given by equation (25a):

$$F_N = \rho A_1 (V_1 - U)^2 \qquad (25a)$$

Where:

F_N = The force exerted on a moving dish [N], and

U = velocity of the dish held normal to the water jet [m/s].

The force exerted on a moving dish held inclined to the direction of water jet is given by equation (25b):

$$F_l = \rho A_1 (V_1 - U)^2 sin^2\theta \qquad (25b)$$

Where:

F_l = The force exerted on a moving dish in the direction of the water jet [N], and

θ = angle between water jet and the dish.

2.3.4 Pump power required

The pump power is determined as follows:

1. The pressure increase required.

This is the difference between the water supply pressure and the spray outlet (nozzle) pressure. It is given by equation (26):

$$\Delta P = P_d - P_{in} \qquad (26)$$

Where:

P_d = Spray nozzle outlet pressure [Pa]

P_{in} = Pressure of water supply to the pump [Pa]

If water is sucked from the same horizontal level, then, $P_{in} = 0.0P_a$

2. Water velocity difference ΔV^2.

The difference in water velocity is obtained using equation (27) given as:

$$\Delta V^2 = V_2^2 - V_{in}^2 \qquad (27)$$

Where:

V_d = Discharge velocity of sprayed water [m/s], and

V_{in} = Velocity of water supply to the pump by external pressure (P_{in}) [m/s].

The water velocity at the pump inlet is assumed to be zero when the pump is not in operation, therefore, during pump operation; the only velocity of water at pump inlet is the pump suction velocity. Thus, V_{in} = 0.0m/s at P_{in} = 0.0Pa.

3. Datum difference.

This is the differences in the height of water column of spray arm exit and at pump entrance, and is obtained using equation (28),

$$\Delta Z = Z_s - Z_{in} \tag{28}$$

Where:

Z_s = datum height of spray nozzle above supply source [m], and

Z_{in} =datum height of pump suction pipe from water supply source [m].

4. Pressure head losses h_l .

This is the total losses in the pipe and joints. It is given by equation (29) as:

$$h_l = \frac{0.5\, V_2^2}{2g} + \frac{V_1^2 - V_b^2}{2g} + \frac{0.5\, V_1^2}{2g} \tag{29}$$

5. Total pressure head

The total pressure head required for effective washing of dishes (h) is determined using equation (30):

$$h = \frac{\Delta p}{\rho g} + \frac{\Delta v^2}{2g} + \Delta z + h_l \tag{30}$$

Where:

ρ = density of water [kg/m^3].

6. Pump power requirement

The pump power required is calculated from equation (31) given as:

$$\dot{W} = \dot{m}gh \tag{31}$$

Where the mass flow rate, $\dot{m} = \rho Q_2$

Hence the power required is also expressed in the form of equations (32)

$$\dot{W} = pQ_2gh \tag{32a}$$

or in horse power as,

$$\dot{W} = \frac{pQ_2gh}{746} \tag{32b}$$

2.3.5 Motor power required

The weight of water to be rotated is given by equation (33),

$$W_w = \frac{\rho\pi\, \mathrm{d}_1^2 L}{4} \tag{33}$$

the weight of steel pipe to be rotated is given by equation (34),

$$W_p = \rho_s \frac{\pi L}{4} (d_0^2 - d_1^2) \tag{34}$$

and the total resisting force is obtained using equation (35),

$$F_r = W_w + W_p \tag{35}$$

Where:

ρ_s = density of steel [kg/m^3],

L = length of Pipe 1[m], and

d_0 = external diameter of pipe 1[m].

The resisting Torque is obtained using equation (36),

$$T_R = F_r \times r_p \qquad (36)$$

Where:

F_r = resisting force [N], and

r_p = radius of pulley on pipe [m].

The actual torque is the resisting torque increase by a factor, η_3, which account for the torque exerted on the pipe due to rotation in the bearings. η_3 is assigned a value of 1.5 based on standard design procedure of pipes. Hence the actual torque is given by equation (37),

$$T = 1.5\, T_R \qquad (37)$$

The motor power in needed is given by equation (38),

$$P = \frac{2\pi\, N\, T}{60} \qquad (38)$$

Where:

N = speed of rotation of the spray required [rpm].

2.3.6 Pulley sizing

The size of pulley on pipe1 is determined using the relation presented in equation (39):

$$D_p = \frac{N_p}{N_m} \times D_m \tag{39}$$

Where:

D_p = diameter of pulley on pipe 1 [m],

D_m = diameter of pulley on motor [m], and

N_m = speed of motor shaft [rpm].

2.3.7 Belt selection

The distance between the two pulleys for this design is less than 8m therefore, a type V – belt is the most suitable for the design. The length of belt need is determined using equation (40),

$$L = \frac{\pi}{4}(D_p + D_m) + 2C + \frac{D_p^2 - D_m^2}{4C} \tag{40}$$

Where:

C = center distance between the two pulleys [m].

2.3.8 Power requirement of heater coil

The Power required by the heating coil is obtained using equation (41) given as:

$$H = \rho Q_2 c_w (T_2 - T_1) \tag{41}$$

Where:

T_1 = unheated water temperature [K]

T_2 = water temperature required for washing [K]

c_w = specific heat capacity of water [J/kg.K].

2.3.9 Total power required by the dish washing machine

The total power required to operate the machine is sum of the power consumed by the water pump, electric motor and the heating coil. It is obtained using equation (42) given as:

$$P_t = \dot{W} + P + H \qquad (42)$$

2.3.10 Current rating of the dish washing machine

The current rating of the machine is obtained using equation (43) given as:

$$I = \frac{P_t}{pf \times V} \qquad (43)$$

Where:

pf = power factor [-],

V = voltage [V], and

I = current rating [A].

2.4 Calculation of washing index

The overall washability index, OWI is determined using equation (44) given by:

$$OWI = \frac{WI_D \times NS_D \times WI_C \times NS_C \times WI_S \times NS_S}{NS_D \times NS_C \times NS_S} \qquad (44)$$

Where:

WI = washing index (100 ≤ WI ≤ 10), and

NS = number of pieces specified for Dishware (D), Ceramic cups (C) and Flatwares (F)

3.Results

The results of the major parameters necessary for the design of the special purpose dish washing machine is present in this section. A MATLAB program was developed based on the formulas in section 2 and used for the design calculations.

3.1 Input Parameters

The input data for analysis and components sizes computations are obtained from standard text, published journals, and by direct measurements.

The basic parameters such as the water supply pressure and the water temperature were obtained from the standard code for dishwasher construction found in [11].

These parameters were imputed into a MATLAB program written based on the design formulas recorded in chapter three of this work. The input data are tabulated in Table 1 below.

Table 1: Input data for analysis

S/N	Parameter	Symbol	Unit	Value
1	height of sprayed water	h_s	m	0.8
2	Discharge pressure required for washing	P	KPa	300
3	Diameter of spray nozzle	d_n	m	0.002
4	Numbers of spray nozzle	n	_	30
5	Efficiency of joint in the spray arm	η_1	_	0.75
6	Efficiency of joint in the heat exchanger	η_2	_	0.75
7	Difference in height of spray arm and heat exchanger	Z_s	m	0.25
8	Length of heat exchanger	Z_1	m	0.14
9	Diameter of heat exchanger	d_b	m	0.14
10	Length of pipe1	L	m	0.2
11	Rotational Speed of spray arm	N	rpm	50
12	Speed of Motor	N_m	rpm	100
13	Diameter of pulley on motor	D_m	m	0.05
14	Acceleration due to gravity	G	m/s^2	9.81
15	Density of steel	ρ_s	kg/m^3	7850
16	Density of water	P	kg/m^3	1000
17	Water supply temperature	T_1	^0C	20^o
18	Max. Water supply temperature	T_2	^0C	45^o
19	Specific heat capacity of water	c_w	J/kgk	4200
20	Supply voltage	V	V	220
21	Power factor	Pf	-	0.8

3.2 Output parameters

The data in Table 1 were inputted into a computer program executable on MATLAB© written based on the formulas in section 2 of this paper. The program was executed and the computation result in Table 2 below was obtained.

Table 2: Computation Result

S/N	Parameter	Symbol	Unit	Value
1	Flow speed at spray nozzle	V_s	m/s	3.96
2	Flow speed in pipe 1	V_1	m/s	3.71
3	Diameter of pipe 1	d_1	mm	13.08
4	Flow speed in heat exchanger	V_b	m/s	0.043
5	Flow speed in pipe 2	V_2	m/s	1.35
6	Diameter of pipe 2	d_2	mm	24.99
7	Total pressure head loss in flow line	H	m	34.85
8	Pump power required	W_{hp}	Hp	0.304
9	Diameter of pulley on pipe 1	D_p	m	0.025
10	Center distance between pulleys	C	m	0.17
11	Motor power required	P_{hp}	Hp	7.9e-6
12	Length of belt needed	L_p	M	0.269
13	Heater Power required	H	Watt	2230
14	Total power required	P_t	Watt	2457
15	Electric current rating of the machine	I	A	13.96

3.3 Design specification

The specification for the fabrication of the special purpose dish washing machine is presented in Table 3. The values were carefully chosen based on the results of the design computation, putting other factors into considerations.

Table 3: Design specifications

S/N	Component	Dimension/size	Material	Quantity
1	Tray	530x530x81mm	Mild steel	1
2	Spray arm	460x14.2x18.1mm	Galvanized steel	0.5
3	Heater	Ø8.5x908x0.5mm	Platinum	1
4	Pipe 1	Ø19x250 mm	Galvanized steel	1
5	Pipe 2	Ø25x200 mm	PVC	1
6	Inlet hose	1500 x 15.3 xl.5mm	Rubber	1
7	Discharge hose	2000 x 25 x 3.5mm	Rubber	1
8	Frame	600x600x800mm	Mild steel	2
9	Wall of wash chamber		Stainless steel plate	1
10	Pump size	0.3 hp		1
11	Motor size	0.1 hp		1
13	Pin Plug	15A		1
14	Heater size	2200 watt		1
15	Supply wire	Ø2.5mm x IC x 3	Copper	1 unit
16	Dish Rack	260 x 260 x 530mm	Stainless steel	2

4. Discussions

From the results of the computations as presented in Table 2, it is seen that for this design, that the minimum internal diameter of each supply pipe is 13.08 mm. This implies that for the dishwasher to be able to produce enough water jet to clean dishes at the computed flow speed of spray nozzle of 3.96 m/s, then the minimum internal diameter of the supply pipe should not be less than 13.08 mm. From Table 3, the internal diameter of the supply pipe is chosen to be 19 mm, for best production of water jet. The flow velocity at the spray nozzle whose value is obtained as 3.96 m/s which is greater than the flow velocity in pipe 1 (3.71 m/s) is an indication that the basic laws of flow through a pipe have been validated in this design. Thus, this dish washing machine will operate at maximum capacity when fabricated, assuming all manufacturing errors are minimized. Also, the pump power requirement as obtained from computations and presented in Table 2 is 0.304 Hp (or 0.227 kW). This value is indicative of the domestic use of this deign of dishwasher, being within range of specifications of pumps for small appliances. It is also seen from Table 2 that the computed electric current rating of the machine is 13.96 A. Again, this falls within the secondary load range (10 -20 amperes) which flows in most homes [8]. Finally, the pressure due to the force exerted by the water jet produced, is negligible compared to both the tensile strength (1138 MPa) and compressive strength (2400 MPa) of ceramics (Alumina Porcelain) or any other ceramic, and hence cannot break any of the ceramic dishes.

5. Conclusion

Hand washing a common load of dishes, about twelve place settings, typically requires over eighty liters more water than a dishwasher [6]. This work was designed to take less quantity of water compare to that wasted on manual hand washing of plates. In this paper, the design of a special purpose dish washing machine was successfully carried out. Applying the overall washability index and performance standard index of dish washers [9], the capacity of the machine is approximately 3 plates per minutes (that is, 20 plates per batch to be washed in 7 minutes), from simulations carried out. The designed dishwashing machine, when fabricated will be very efficient and easy to operate. This work has established the fact that washing machines of different capacities can be manufactured locally in Nigeria without compromising standards. The work is rich with mechanical engineering design and so could be used for instructing undergraduate of mechanical, and mechatronic engineering.

6. Recommendations

Further research and design can be carried out on this dishwashing machine with the aim of determining how water consumption of the machine can be reduce with quality of washing still remaining undiminish. Research can also be carried out to determine the conditions and factors that can enhance dish washing machine operation and how such factors can be incomporated into its design without creating unfriendly environment. It is also recoommeded that a fabrication of this design is carried out and a performance analysis done to compare those obtained from computed results. Finally, this design can be modified to handle dishes made of materials other than ceramics.

References

[1]. I. F. Odesola and O. A. Afolabi. "Design, Fabrication and Performance Evaluation of a Domestic Dish Washing Machine". International Journal of Science and Technology Bahir Dar, Ethiopia, Vol. 1(1), pp. 164-173, 2012.

[2]. A. Sharma, H. Jain, C. O. Joseph and G. M. Lugo. "Influence of the manufacturing process on

corrosion behavior of soda-Li. silicate glassware". Journal of the American Ceramics Society, 86: 1669, 2003.

[3]. N. S. Castro. "Energy and Water Consumption Testing a Conventional Dishwasher and an Adaptive Control Dishwasher". NIST. Proceedings of the International Appliance Technology Conference, Columbus OH, May 1997.

[4]. A. D. Dhale, L. S. Ghodke, P. U. Hase, S. V. Jarag, and S. S. Shelar. "Design and Development of a Semi-Automatic Dishwasher". International Journal of Engineering Research and General Science, vol. 3(3), pp. 108 – 112, 2015.

[5]. S. S. Hedaoo, C. C. Handa and V. D. Dhopte. "Design and Fabrication of Semi-Automatic Dish and Utensile Washing Machine". International Journal of Scientific Research and Development, vol. 4(05), pp. 1470 – 1473, 2016.

[6]. G. Brian. "Investigating the Insufficient Cleaning of Dirty Dishes in Confined Living Spaces and the Design of a Highly Marketable Dishwasher Solution". Bachelor of Science Research paper, University of Virginia, United States of America, 2010.

[7]. E. H. David, S. P. Danny, and H. H. Andreas. "How Energy Efficient are Modern Dishwashers". ACEEE Summer Study on Energy Efficiency in Buildings, Florida, 2008.

[8]. NSF International. "Residential Dishwashers". United States of America. NSF/ANSI 184, American National Standards Institute, ANSI, March 2003.

[9]. ANSI/AHAM. "American National Standards on Household Electric Dishwashers". United States of America. ANSI/AHAM-1-1992

[10]. T. Andy. "Can you connect a dishwasher to the hot water supply?". www.whitegoodshelp.co.uk/can-you-connect-a-dishwasher-to-the-hot-water-supply, Feb. 7, 2017 [Jan. 12, 2018].

[11]. NSF/ANSI. "NSF International Standard/ American National Standards for Food Equipment". United States of America. NSF/ANSI-2012.

[12]. R. S. Khurmi and J. K. Gupta. A Textbook of Machine Design. New Delhi: S. Chand and Company Ltd, 2010 reprint, pp. 611 – 645.

[13]. R. K. Rajput. A Textbook of Fluid Mechanics and Hydraulic Machines. New Delhi: S. Chand and Company Ltd, 2012 reprint, pp. 535 – 614.