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Design, Fabrication and Performance Evaluation of a Domestic Dish Washing Machine

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Abstract

Plate washing is a daily activity across the globe which involves a lot of energy to accomplish manually or mechanically. The objective of this work is to design and fabricate a dish washing machine that is efficient and easy to operate. Stainless steel and mild steel was used for the construction of the machine considering their availability, cost reduction and corrosion *resistance. The motor used a power of 0.75hp (559.5 W), voltage of 240V and a speed of rotation of "1200 r.p.m" which was reduced to "100 r.p.m" using a reduction gear of velocity ratio (V.R) "12:1", the shaft torque being "53.4 N-m". The plates were washed and rinsed in a separate basin using a liquid detergent and clean water following appropriate measure per cycle. Detailed design drawings of all the machine parts were drawn using AutoCAD. The performance analysis of the machine shows that the number of plates washed and the time taken were 20 plates per minute (1min), 5 plates per minute for the machine and manual operation respectively. The capacity of the machine is 20 plates per minute (1880 per hour). The machine washes plates without breakages.*

Key words: Washing machine, motor, transformer, gear, plates and detergent

Introduction

Pots and pans are washed by hand by scrubbing them in a detergent and water mix, immersing them in a rinse of plain water, and then immersing them in a water/sanitizer solution for a period. Silverware is washed by placing loose silverware in a tray, washing them several times like this, then sorting them into circular holders, and washing them again in the dishwasher. A dishwasher may be known as a pan-diver, from the French "plongeur", and made famous by George Orwell in down and out in Paris and London. Commonly used also is the term "KP" for Kitchen Porter or Kitchen Police, who would have a variety of other duties. The area where dishes are washed, particularly in foodservice is sometimes also called a "dish-pit" (Sharma et al, 2003).

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. In British English the term washing up is more common. There are cultural divisions over rinsing and drying after washing. Unlike manual dishwashing, which relies largely on physical scrubbing to remove soiling, the mechanical dishwasher cleans by spraying hot water, typically between 55 to 75 °C (130 to 170 °F) at the dishes, with lower temperatures used for delicate items (William, 2008). Unlike manual dishwashing, which relies largely on physical scrubbing to remove soiling, the mechanical dishwasher cleans by spraying hot water typically, between 55 to 75 °C (130 to 170 °F), at the dishes, with lower temperatures used for delicate items. A mix of water and detergent is used for cleaning purposes, followed by clean water to remove the detergent residue. Some dishwashers have multiple wash and rinse periods within the complete cycle.

The first dish washer was invented in America in1850, Joel Houghton patented a wooden machine with a hand-turned wheel that splashed water on dishes, it was hardly a workable machine, but it was the first patent (William, 2008). The first reports of a mechanical dishwashing device are of an 1850 patent by Joel Houghton of a hand-powered 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. Another patent was granted to L.A. Alexander in 1865 that was similar to the first but featured a hand-cranked rack system. Neither device was practical or widely accepted. One of the earliest washing machines were patented in 1858 by Hamilition E. Smith, of Pittsburgh, pa. This washer was operated by rotated paddles mounted on a vertical axis inside the tub. Another manually operated washer initiated the scrubbing action of a wash board (Sharma et al, 2003). These early machines met with little success, for often the plat become tangled, or torn. It was not until 1907 that a practical application was developed for operating a washer by a motor. By 1912 nearly all the laundry manufacturers in the U.S and the Europe were making machines driven by electric power, but even with the boost of sales during World War I, it was until 1920 that their sales in U.S. passed the million mark. The tubs of the 1st washing machines were constructed of wood, but the manufacturers gradually turned to metal: copper, galvanized steel, aluminium and zinc. By 1961 practically all were being made of porcelain enamel because of its resistance to strong washing powders and to all temperature of water.

Materials for construction

The following materials were carefully chosen for the construction of the dish washing machine. These were:

a. Metal steel	b.Stainless steel	c. Electric motor
d. Reduction gear	e.Water tap	f. Shaft
g. Switches	h.Drainage hose	i. Sealing (soft) brush

j.Transformer (240V) k. Regulator l. 2 Round pipe ($2^{3/4}$")

m. Electrode

Design calculations:

The design calculations of three (3) basic machine components; (i) motor power (ii) shaft and (iii) reduction gear are presented below.

Motor Power:

The power required for the transmission of torque required was calculated from the equation:

P = V x I x 1.732 or

P = (T x N) / 5250

Where: P = Motor power (Hp / Watt); V= Voltage (V); I = Current (A); T = Torque (N-m); N = Speed of rotation (r.p.m.)

The earlier is to be used for estimating the power input to the motor while the latter is for estimating power output. The difference is wasted energy, which manifests itself as heat produced by the motor. Assuming the input voltage is 240V and current of 1.345A,

P= 240 x 1.345 x 1.732

P= 559.5 W

Design of worm gear.

Speed of worm is taking as the speed rotation of the motor = 1200 r.p.m.

The speed is expected to be reduced to 12:1, i.e velocity ratio (V.R) = 12

Let N_G = Speed of the worm gear in r.p.m.

From velocity ratio relation,

$$\text{V.R.} = \frac{N_W}{N_G} \; or \; \frac{N_W}{V.R} = \frac{1200}{12} = 100\ r.p.m$$

∴ Torque transmitted will be,

$$T = \frac{P\,x\,60}{2\pi N_G} = \frac{559.5\,x\,60}{2\pi\,x\,100} = 53.4 \text{ N-m}$$

Design of shafts

The shafts are designed on the basis of (i) strength and (ii) rigidity and stiffness and were made from commercial steel.

From the formula:

$$\frac{T}{J} = \frac{\tau}{r}$$

Where T= Twisting moment (or torque) acting upon the shaft

J= Polar moment of inertia of the shaft about the axis of rotation

= Torsional shear stress

R = Distance from the neutral axis to the outer most fibre = d/2: where d is the diameter of the shaft

For a solid shaft, polar moment of inertia is:

$$J = \frac{\pi}{32} x d^4$$

Therefore, the above equation becomes:

$$T = \frac{\pi}{16} x \tau x\, d^3$$

The torque through which the shaft will be rotating will therefore be:

Using the formula

$$T = \frac{P\,x\,60}{2\,\pi\,N} = \frac{559.5\,x\,60}{2\pi\,x\,100} = 53.4 \text{ N-m}$$

The expected torque of the shaft to rotate will be: **53.4 N-m**

The diameter of the shaft will be,

$$T = \frac{\pi}{16} x \tau x\, d^3 = \frac{\pi}{16} X50\,(d)^3 = 9.82\,(d)^3$$

d^3 = 53.4 / 9.82 = 1.758m = 2 x 10^3 mm

The American Society of Mechanical Engineers (ASME) code equation for a solid shaft having little or no axial loading is:

$$d^3 = \frac{16}{\pi S_s}\sqrt{(K_b\,M_b)^2 + (K_t M_t)^2}$$

Where d = diameter of the shaft

Ss = Allowable stress of the shaft

M_t = Torsional moment on the shaft (Nm)

M_b = Bending moment on the shaft (Nm)

K_t = combined shock and fatigue factor applied to bending moment

K_b = shock and fatigue factor applied to torsional moment.

For rotating shaft, K_t = 1.5, K_b=2.0

The shear (τ) and bending (σ) stresses on the outer surface of a shaft, for a torque (T) and bending moment (M) of a solid circular section are:

The Dishwashing machine

The entire body of the dishwasher i.e the outer surface was made of metal sheet which is of dimension 90cm by 60cm by 77cm. Dishwasher (metal sheet): Length = 90 cm; Breath = 60 cm; Width = 77cm

The volume of the dishwasher = (90 x 60 x 77) cm^3

= 415800 cm^3

The Washing basin

This is the section where plates are washed and has the following dimensions:

Length = 54cm; Breadth = 31cm; Height = 25cm

Volume = (LxBxH) cm^3

= (54 x 31 x 25) cm^3 = 41850 cm^3 = 41.85 litres

The Rinsing basin

This is the second basin where the plates are rinsed with clean water after washing. The plate has these dimensions: Length = 54cm; Breadth = 23cm; Height = 25cm

Volume = (L x B x H) cm^3

= (54 x 23 x 25) cm^3

= 31050 cm^3

= 31.05 litres.

Figure 1: The pictorial view of the washing machine

Detergent used:

1. Green dishwashing liquid (capacity: 200ml)
2. Mama lemon dishwashing liquid (capacity: 550ml)

Note: The detergent was completely dissolved in water before used.

Results and discussion

Series of test were carried out in order to determine the performance and efficiency of the machine. This was done by comparing the rate of washing with the designed dish washer to the hand-washing (manually). In carrying out these test, six (6) parameters were taken into consideration, they are: no of plate washed; quantity of water used in washing (litres); quantity of detergent used (ml); time of washing (sec); quantity of water used in rinsing (litres); time of rinsing (sec). These are shown in tables 1 and 2 below. Fig.1.0 shows the designed dish washing machine. Table 1 shows how the designed machine performed under loads.

Table 1: Performance evaluation of the Machine

S/N	No of Plate	Quantity of water used in washing (litres)	Quantity of Detergent used (ml)	Time used in Washing (sec)	Time used in Rinsing (sec)	Quantity of Water used in Rinsing (litres)
1	1	0.2	1	5	3	0.5
2	4	0.5	1.5	10	4	1
3	10	1	4	30	15	3
4	30	2	8	90	45	5
5	60	3	10	180	100	10
6	90	4	15	240	120	12
7	100	4	15	260	160	12

Table 2: Performance parameters using manual dishwashing

S/N	No of Plates	Quantity of water used in washing (litres)	Quantity of Detergent used (ml)	Time used in Washing(sec)	Time used in Rinsing (sec)	Quantity of Water used in Rinsing (litres)
1	1	0.5	1	15	5	1
2	4	1	1.5	40	10	2
3	10	2	4	60	20	4
4	30	3	10	150	60	6
5	60	3	15	240	120	12
6	90	5	20	400	240	15
7	100	5	20	400	240	15

Conclusion

The design, construction and evaluation of a dish washing machine were successfully carried out. The capacity of the machine was 20 plates per minutes (i.e 1880 plates per hour). The designed dishwashing machine is 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.

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