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Design and Fabrication of Automatic Drain Cleaner

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ABSTRACT

This paper describes about the design and fabrication of automatic drain cleaner. There are a large number of machines used for removing out the wastes from drains. Nowadays, automation plays a vital role in all industrial applications. The automatic drain cleaner can be used in domestic, industry, large plants, irrigation and drainage cleaning system. In order to overcome the problems in manual drain cleaning, Automatic Drain Cleaning System is implemented to clean and control the drainage level. Every automatic drain cleaner has four main components, namely; DC motor, 12 V battery, chain drives and shafts. The rotational speed of the drive shaft is 26 rpm. But in this paper, only shaft design is calculated.

The required power from a motor to drive this shaft is 60 W. In designing shaft, chain tension, sprocket load and bearing load are taken into account and also bending moment and torque are included.

KEYWORDS: *Automatic Drain Cleaner, Bending Moment, Chain Drives, Shaft.*

I. INTRODUCTION

Automatic Drain Cleaner overcomes all sorts of drainage problems and promotes blockage free drains promoting continuous flow of drain water. In the modern area there have been adequate sewage problems where sewage water needs to be segregated to clean our surrounding environment.

Our proposed system is used to clean and control the drainage level using auto mechanism technique. Auto-mechanism is the major controlling unit and the drainage level a monitor by municipal. In this system hand wheel, chain, driver, bucket, and frame are used. The waste and gases produced from the industries are very harmful to human beings and to the environment, waste like bottles, etc. Floating in drain is lifted by teeth which are connected to chain.

These administration strategies for a scope of hardware for overseeing and controlling amphibian vegetation is being used today, intended for particular plant sorts and for operation in particular sea-going environments. The device is placed across the drain so that only water flows through lower grids. Floating in drain is lifted by teeth which are connected to chain. This chain is attached to gears driven by motor.

When the motor runs, the chain starts to circulate making teeth to lift up. The waste materials are lifted by teeth and are stored in waste storage tank. DC motor plays a major role in many applications; dc motor is required to be rotated in clockwise and counter clockwise directions.

II. Types of Automatic Drain Cleaner

Two types of Automatic Drain Cleaner are as follows:

A. Automatic Drainage Cleaning System by using Solar Panel and
B. Automatic Drainage Cleaning System by using Simple Formed.

A design, "Automatic Drain Cleaning System" is implemented to use in an efficient way to control the disposal of wastages as shown in Figure 1. With regular filtration of wastages, clearance of gaseous substance is treated separately and monitors the disposal in frequent manner.

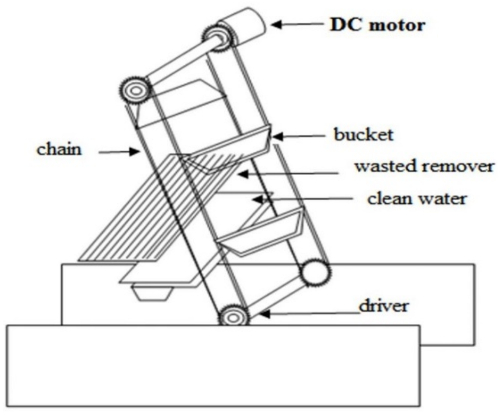

Figure1. Automatic Drain Cleaner

Every dynamic spring is subject to these constraints where variation of forces and alignment take place, to find a solution for the problem of water logging due to plastic, metal, others, and to treat problems like malaria, typhoid, etc. caused due to water accumulation. It can be said that major factors that affect the strength of the machine are design parameters, material selection, raw material defect, and surface imperfection. It is seen that design parameters i.e. operating modes, operating temperature, and imperfections.

III. Components of Automatic Drain Cleaner

The main components of "Automatic Drain Cleaner" have been developed.

They are:

A. DC Motor
B. Sprockets
C. Bearings
D. Chain Drivers
E. Shaft
F. Sheet Metal and
G. Bucket.

Sprockets

A sprocket or sprocket wheel is a profiled wheel with teeth, or cogs, that mesh with a chain; track or other perforated or indented material as shown in Figure 2. The name sprocket" applies generally to any wheel upon which radial projections engage a chain passing over it.

Figure2. Sprocket

It is distinguished from a gear in that sprockets are never meshed together directly, and differs from a pulley in that sprockets have teeth and pulleys are smooth. Sprockets are used in bicycles, motorcycles, cars, tracked vehicles, and other machinery to transmit rotary motion between two shafts where gears are unsuitable or to impart linear motion to a track, tape etc.

Chain Drive

Chain drive is a way of transmitting mechanical power from one place to another. It is often used to convey power to the wheels of a vehicle, particularly bicycles and motorcycles. It is also used in a wide variety of machines besides vehicles. Most often, the power is conveyed by a roller chain, known as the drive chain or transmission chain, passing over a sprocket gear, with the teeth of the gear meshing with the holes in the links of the chain.

The gear is turned, and this pulls the chain putting mechanical force into the system as shown in Figure 3. Another type of drive chain is the Morse chain. This has inverted teeth. Sometimes the power is output by simply rotating the chain, which can be used to lift or drag objects. In other situations, a second gear is placed and the power is recovered by attaching shafts or hubs to this gear. Though drive chains are often simple oval loops, they can also go around corners by placing more than two gears along the chain; gears that do not put power into the system or transmit it out are generally known as idler-wheel. By varying the diameter of the input and output gears with respect to each other, the gear ratio can be altered.

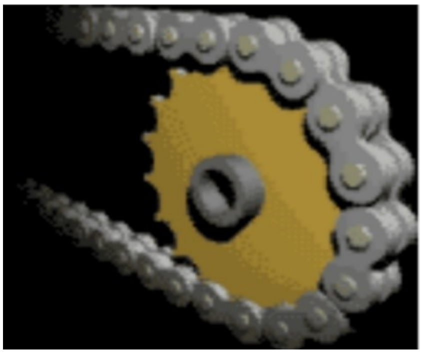

Figure 3. Chain Drive

Shaft

A shaft is a rotating machine element, usually circular in cross section, which is used to transmit power from one part to another, or form a machine which produces power to a machine which absorbs power as shown in Figure 4. The various members such as pulleys and gears are mounted on it.

Figure4. Spline Shaft

IV. Working of Automatic Drain Cleaner

A. The automated mechanism is basically designed to filter out this solid waste of the running drains and hence removing the possibility of any blockage of the flowing waste water.
B. The turbine is the power generating element that functions on the hydraulic power and hence then drive the chain mechanism.
C. The chain mechanism is being fitted with the wire mesh filter that just picks up the solid waste while the liquid waste flows through the mesh.
D. The size of mesh holes can be adjusted in order to decide the different size of solid waste we are working on.
E. The system is being adjusted at a angle so that mesh is able to hold the solid waste.
F. The storage box is kept where the solid waste is collected and later that box can be cleaned to remove the collected waste.

V. Design Theory

Design of the Shaft

The shaft must have adequate torsional strength to transmit torque and not be over stressed. Shafts are mounted in bearings and transmit power through devices such as sprockets and chains. Components such as sprockets are mounted on shafts using keys. Shaft must sustain a combination of bending and torsional loads.

A shaft is a rotating machine element which is used to transmit power from one place to another. The power is delivered to the shaft by some tangential force and the resultant torque set up within the shaft permits the power to be transferred to various machines linked up to the shaft.

In designing shaft on the basic of strength, the following cases may be considered:

A. Shaft subjected to twisting moment or torque only
B. Shaft subjected to bending moment only
C. Shaft subjected to combined twisting and bending moments
D. Shaft subjected to axial loads in addition to combined torsional and bending loads.

Work Done and Power,
Work done per minute = (Force) × (Distance)
=(Average) × (Angular displacement)

$$= T \times \frac{2 \cdot \pi \cdot N}{60} \quad 1$$

Where, T = torque of motor
N = number of speed (rpm)

Sprocket Load on the Shaft

$$p = D \sin\left(\frac{\theta}{2}\right)$$

$$= D\sin\left(\frac{180^{O}}{T}\right) \quad 2$$

Where, p = pitch
T = number of teeth

Centrifugal Tension in the Chain

$$F_C = m \cdot v^2 \text{ (Newton)} \quad 3$$

Where, F_C = centrifugal tension
m = total mass on the chain
v = speed of the chain

Chain Length,

$$L = K \times p \quad 4$$

$$K = \frac{T_1 + T_2}{2} + \frac{2x}{p} + \left[\frac{T_2 - T_1}{2\pi}\right]^2 \frac{p}{x} \quad 5$$

Where, L = the length of the chain
K = number of chain links
p = pitch
x = the center distance
T = number of teeth

Tension in Chain due to Sagging,

$$F_S = k \cdot mg \cdot x \text{ (Newton)} \quad 6$$

Where, m = mass of the chain in kg per meter length
x = center distance in meters
k= constant which takes into account the arrangement of chain drive
= 2 to 6, when the center line of the chain in inclined to the horizontal at an angle less than 40^{O}
= 1 to 1.5, when the center line of the chain in inclined to the horizontal at an angle greater than 40^{O}

Factor of Safety,

$$\text{Factor of safety}, n = \frac{W_B}{W} \quad 7$$

Where, $W_B = 106p^2$ (in Newton) for roller chains
= 106p (in Newton) per mm width of chain for silent chains

$$W = \frac{\text{Rated power}}{\text{Pitch line velocity}}$$

Service Factor,

$$K_S = K_1 \times K_2 \times K_3 \quad 8$$

Where, K_S = service factor
K_1 = load factor
K_2 = lubrication factor
K_3 = rating factor

Power Transmitted,

$$P = \frac{W_B \times v}{n \times K_S} \quad 9$$

Where, W_B = breaking work
v = speed of the chain
n = factor of safety
K_S = the service factor

Tangential Driving Force,

$$F_T = \frac{\text{Power transmitted (inwatts)}}{\text{Speed of chain in m/s}} = \frac{P}{v} \quad 10$$

Equivalent Twisting Moment (T_e)

$$T_e = \sqrt{(K_m \times M)^2 + (K_t \times T)^2} \quad 11$$

Where, T_e = equipment twisting moment
K_m = shock factors
K_t = combined fatigue
M = maximum bending moment
T = torque of motor

Diameter of the Shaft,

$$T_e = \frac{\pi}{16} \times \tau \times d^3 \quad 12$$

Where, T_e = equivalent twisting moment
τ = maximum shear stress
d = shaft diameter

Angle of Twist,

$$\text{Angle of twist, } \theta = \frac{TL}{GJ} \quad 13$$

Where,θ = the angle of twist (Degree)
T = the applied torque (Nm)
L = shaft length (m)
J = polar moment on inertia of shaft cross section (m^4)
G =shear modulus of elasticity of shaft (N/m^2)
J = Polar movement of inertia = $\frac{\pi \times d^4}{32}$
d = diameter of shaft

Angle of Deflection,

$$\theta = \frac{584 M_t L}{G d^4} \qquad 14$$

$$\theta = \theta_1 - \theta_2 \qquad \text{(Same direction)}$$

$$\theta = \theta_1 + \theta_2 \qquad \text{(Different direction)}$$

Where, M_t = Torque (Nm)
L = shaft length (m)
G = shear modulus of elasticity of shaft (N/m^2)
d = diameter of shaft

$$\sigma = \frac{T_1}{bt} \qquad 15$$

Where, σ = Stress of belt
T_1 = Tension in tight side
B = Width of belt
t =Thickness of belt
Length of Open Belt Drive,

An open belt drive is used to rotate the driven pulley in the same direction of driving pulley. The length of belt can be calculate by the following equation.

$$L = \pi(r_1+r_2)+2x+\frac{(r_1 - r_2)^2}{x} \qquad 16$$

Where,r_1 and r_2 =Radii of the larger and smaller pulleys
x =Distance between the centers of two pulleys
L =Total length of the belt
Maximum Tension in the Belt,

The maximum tension in the belt is equal to the total tension in the tight side of the belt.

T= Maximum stress × Cross section area of the belt

$$T = \sigma \times b \times t \qquad 17$$

When, Centrifugal tension is considered,

$$T = T_1 + T_C \qquad 18$$

Where, σ =Maximum safe stress
B =Width of the belt
t =Thickness of the belt
T_1=Tension in the tight side
T = Maximum tension in the belt
Centrifugal Tension,

The tension caused by centrifugal force is called centrifugal tension.

$$F_C = mv^2 \qquad 19$$

Where, F_C=Centrifugal tension
m=Mass of belt per unit length in kg
v=Linear velocity of belt in m/s
Ratio of Driving Tension for Flat Belt Drive,

$$\frac{T_1}{T_2} = e^{\mu\theta} \qquad 20$$

Where, T_1=Tension in the tight side
T_2=Tension in the slack side
μ=Coefficient of friction between belt and pulley θ=Angle of contact

Power Transmitted by a Belt

Power transmitted between a belt and a pulley is expressed as the product of difference of tension and belt velocity.

$$P = (T_1 - T_2)\, v \qquad 21$$

Where, P=Power transmitted by belt
T_1=Tension in the tight side
T_2=Tension in the slack side
v=Velocity of the belt in m/s

Power,
Electrical power is the rate at which electrical energy is converted to another from, such as motion, heat, or an electromagnetic field. The common symbol for power is the uppercase letter P, the standard unit is the WATT, symbolized by W.

$$P = \frac{2\pi \times N \times T}{60} \qquad 22$$

$$T = F \times r \qquad 23$$

$$N = \frac{v \times 60}{\pi d} \qquad 24$$

Where, P =Power (kW)
N=Drive pulley rpm
T=Torque (Nm)
r=Pulley radius (m)
v=Velocity of belt (m/s)
d=Pulley diameter (m)

Relationship between Centripetal Force and Gravity force,

$$F_C = \frac{mv^2}{r} \qquad 25$$

$$F_g = mg \qquad 26$$

Where, F_C=Centripetal force
F_g=Gravity force
m=Material mass in the bucket
v =belt velocity in m/s
g =Gravity acceleration, 9.81 m/s^2

VI. Result for Automatic Drain Cleaner Specification

By using the following specifications, the shaft design of automatic drain cleaner can be calculated. Detailed drawing of automatic drain cleaner is shown in Figure 5.

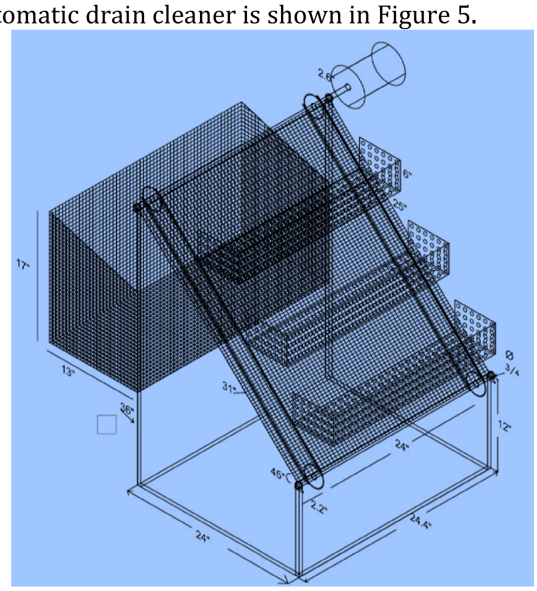

Figure5. Detail Drawing of Automatic Drain Cleaner

Power = 60 W
Sprocket Diameter = 0.04 m
Rpm = 26(Motor)
$\alpha = 45^{O}$ (Sprocket)
PQ = 0.722 m
(Total Length)
PB =CD = 0.045 m
BC = 0.577 m DQ = 0.055 m
$m_{bucket} = 1$ kg
$m_{waste} = 5$ kg
$m_{chain} = 2$ kg

Motor Load on the Shaft,
For Motor Q,

$$T_Q = \frac{P_Q \times 60}{2\pi \times N}$$

$$= \frac{60 \times 60}{2\pi \times 26}$$

= 22.037 Nm

Own weight of Motor,
m = 2 kg
$W_Q = mg$
$= 2 \times 9.81$
= 19.62 N
Sprocket Load on the Shaft,
For sprocket B and C (same diameter),
Number of teeth, T = 14
D = 40 mm

$$p = D \sin\left(\frac{\theta}{2}\right)$$

= 9 mm
Centrifugal tension in the chain,

$$F_C = \frac{mv^2}{r}$$

$$v = \frac{\pi DN}{60}$$ (Same diameter)

$$= \frac{\pi \times 40 \times 10^{-3} \times 26}{60}$$

= 0.054 m/s

$m_{bucket} = 3(1) = 3$ kg
$m_{waste} = 2(5) = 10$ kg
$m_{chain} = 2(2) = 4$ kg
$m = m_{bucket} + m_{waste} + m_{chain}$

$$F_C = \frac{8.5(0.054)^2}{20 \times 10^{-3}}$$

= 1.239 N

Chain Load on the Shaft,
Tension in Chain due to sagging,
Centre distance, x = 914.4 mm
Chain mass, m = 2 kg

$L = K \times p$
$T_1 = T_2 = 14$

$$K = \frac{T_1 + T_2}{2} + \frac{2x}{p} + \left[\frac{T_2 - T_1}{2\pi}\right]^2 \frac{p}{x}$$

$$= \frac{14+14}{2} + \frac{2 \times 914.4}{9}$$

= 217.2
$L = 217.2 \times 9$
= 1954.8 mm

Chain mass,

$$m = \frac{2}{1954.8 \times 10^{-3}}$$

= 1.023 kg/m
$F_S = k \times m \times g \times x$
$F_S = 1 \times 1.023 \times 9.81 \times 914.4 \times 10^{-3}$
= 9.177 N

Power transmitted,
$W_B = 106p^2$

Factor of safety,

$$n = \frac{W_B}{W}$$

$$= \frac{60}{0.054}$$

= 1111.111 N

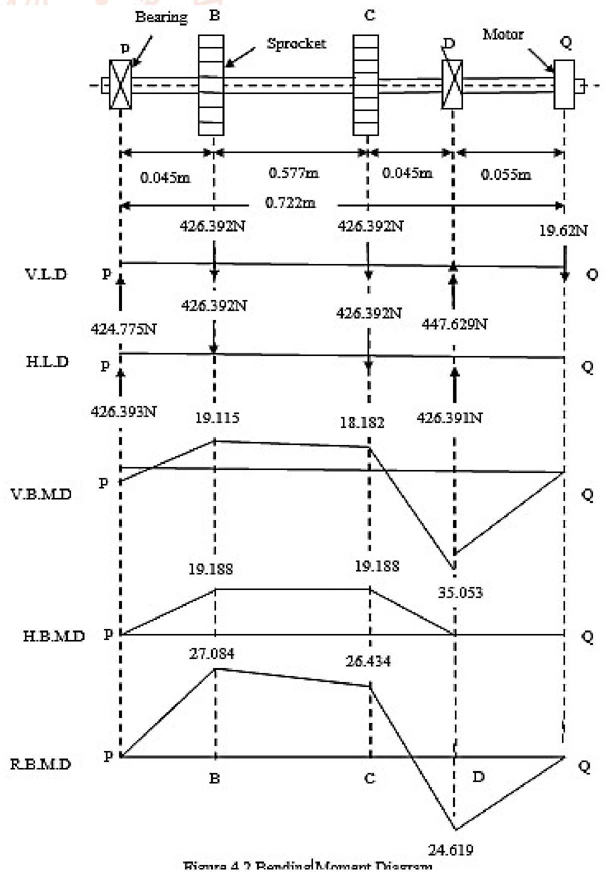

Figure6.Bending Moment Diagram

No.	Calculate data of parts	Result	Unit
1	Own weight of motor	19.62	N
2	Pitch	9	mm
3	Centrifugal tension	1.239	N
4	Sagging tension	9.177	N
5	Tangential force	592.593	N
6	Total load acting on sprocket	603.009	N
7	Resultant B.M at C	26.434	Nm
8	Resultant B.M at D	24.619	Nm
9	Equivalent twisting moment	46.218	Nm
10	Shaft diameter	0.019	m
11	Angle of Twist	0.016	Degree
12	Angle of Deflection	0.294	Degree

Table1. The Calculated Result for Automatic Drain Cleaner

VII. Discussions and Conclusion

In this paper, the design of shaft for drainage cleaning system is calculated. Automatic Drain Cleaner is simple and easy to construct. The Automatic Drain Cleaner is widely used in domestic and industry in every country all over the world. Designing Automatic Drain Cleaner consists of four main components such as DC motor, 12 V battery, chain drivers and shafts. The motor is 60 W DC motor. The mild steel is used for shaft material in this thesis. Depth of the channel is 1feet and height of the channel is 3feet, rate of disposal of waste is considered as uniform, lifter speed and motor speed is also constant.

In design calculation of shaft, the length is 0.722 m and storage tank area is 0.2 m^2. The torque required to rotate the shaft is 22.04 Nm and maximum bending moment due to the load exerted on the shaft is 27.08 Nm. Then, the design diameter 19 mm is obtained. Besides, the angle of twist and the angle of deflection are also calculated in this paper.

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