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Design and Fabrication of Overhead Water Tank Cleaning Machine

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Abstract: Aim of this project is to develop a mechanical system for cleaning 1000 litres water tank. Household water tanks are supposed to provide safe drinking water, as well as water for cleaning, gardening, cooking, and drinking. Most of the time, the water entering the tank contains dust and dirt particles. Sludge or sediment can accumulate over time, contaminate water and cause illnesses in humans such as diarrhoea, cholera, amebiasis, typhoid, and gastroenteritis. Tank cleaning is required because mud, dust and dirt entering the water may settle at the bottom of the tank, resulting in the formation of algae and salt deposits that degrade water quality and impede the flow of water through a pipe. It has been observed that the procedures for cleaning water tanks are manual and a person needs to enter the tank to clean it. Tank cleaning is put off since it requires draining the water first, which is a difficult and time-consuming process. Cleaning the tank becomes more difficult if it is located overhead.

The experimental set-up for this study comprises of a triangular frame that is typically fixed against a wall and kept there. The cleaning is done with a motor-driven roller brush. The brush arrangement moves over a lead screw in an up and down motion. A lead-acid battery supply with a 12-volt capacity and 70Ampere powers each of these motors. To make it simple to transport from one place to another, rotating trolley wheels are mounted to the bottom of the frame. A switch with a current rating of 10 amps is used to turn on and off each motor. Weight of the machine is 18kgs.

The purpose of this project is to reduce human effort while avoiding chemical influence on the health of a person entering the tank for cleaning.

Keywords: Water tank**,** Sludge, Sediment, overhead**.**

1. Introduction

1.1 Necessity of Cleaning Water Tanks:

Cleaning water tanks is necessary to ensure that the water supply remains safe and clean for human consumption. Water tanks can accumulate a build-up of sediment, bacteria, and other contaminants over time, which can lead to health hazards if not properly maintained.

1.2 Reasons for Cleaning Water Tanks:

- Waterborne Internal Diseases
- Skin Diseases
- Bad Taste
- Different Colour

1.3 Methods of Cleaning Water Tanks:

1.3.1 Manual scrubbing: This method involves physically scrubbing the walls and floor of the tank using a brush or sponge with a cleaning solution. The cleaning solution can be a mixture of water and detergent, or a specialized tank cleaning solution. Once the tank has been scrubbed, it is rinsed with clean water.

1.3.2 High-pressure cleaning: This method involves using a high-pressure water jet to clean the walls and floor of the tank. The water jet dislodges any dirt or debris that has accumulated in the tank. The tank is then rinsed with clean water.

1.3.3 Vacuum cleaning: This method involves using a vacuum cleaner to suck out any sediment or debris that has accumulated in the tank. Once the debris has been removed, the tank is cleaned with a cleaning solution and rinsed with clean water.

1.3.4 Ultrasonic cleaning: This method involves using ultrasonic waves to dislodge and remove any dirt or debris that has accumulated in the tank. The waves create microscopic bubbles in the water, which implode and create a scrubbing action that removes any contaminants from the tank. This method is particularly effective for cleaning small, hard-to-reach areas of the tank.

2. 3D Design of Project Model

CATIA (Computer-Aided three-dimensional interactive application) is developed by Dassault systems, it offers a wide range for designing, modeling, analyzing and visualizing products in 3D.Catia is a comprehensive software that offers a wide range of tools for designing and analyzing products. It provides a platform for creating 3D models and assembling parts, making it easier for engineers and designers to create and evaluate product designs. The software also allows users to simulate various real-world conditions, such as stress, heat, and motion, which helps to determine the product's durability and performance. One of the key features of Catia is its parametric modeling capabilities. This means that users can make changes to the design parameters of a product, and the software automatically updates the design accordingly. This feature makes it easier to modify designs during the development process without having to start from scratch each time. Furthermore, it allows engineers and designers to explore different design options and test various scenarios quickly. Catia's user interface is user-friendly and intuitive, making it easy for new users to learn the software quickly. The software offers a variety of tools, including sketching, surface modeling, sheet metal design, and assembly design, among others. This allows users to create complex products with a high level of accuracy and precision.

2.1 Water Tank:

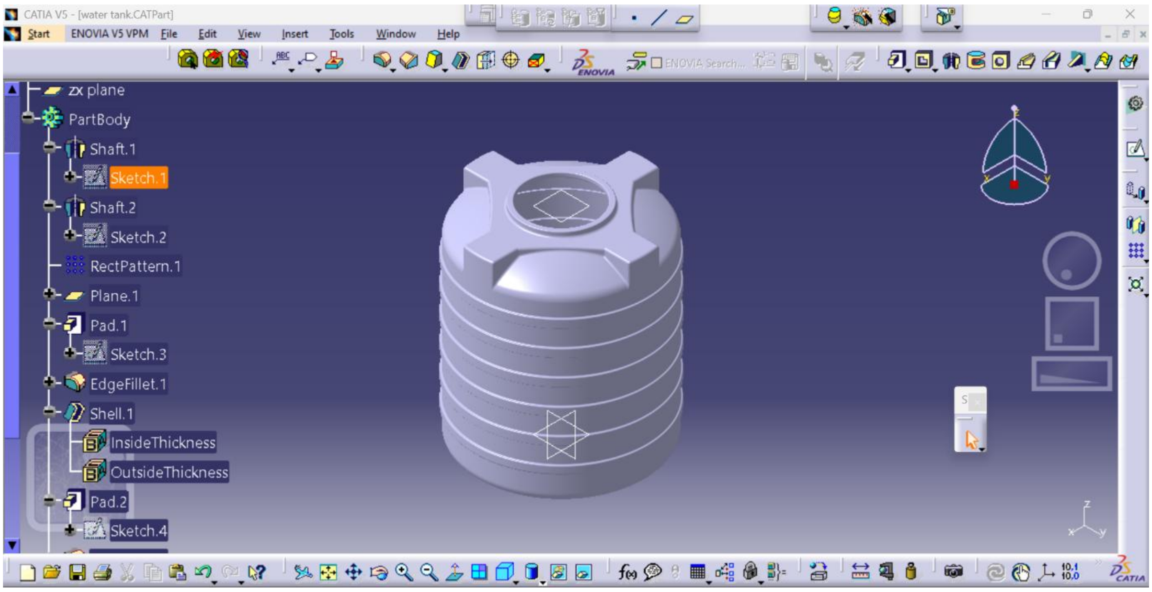

Figure 2.1: Water Tank

A plastic water tank is a type of water storage container made from high-quality plastic materials. Plastic water tanks are commonly used for storing portable water, and they are popular due to their affordability, durability, and ease of installation. They are commonly used in households, commercial and industrial buildings, and agricultural applications, among others.

2.2 Dimensions of tank:

- Capacity :1000litres
- Height :1050mm
- Diameter :1000mm
- Inlet hole Diameter :355mm

2.3 Triangular frame:

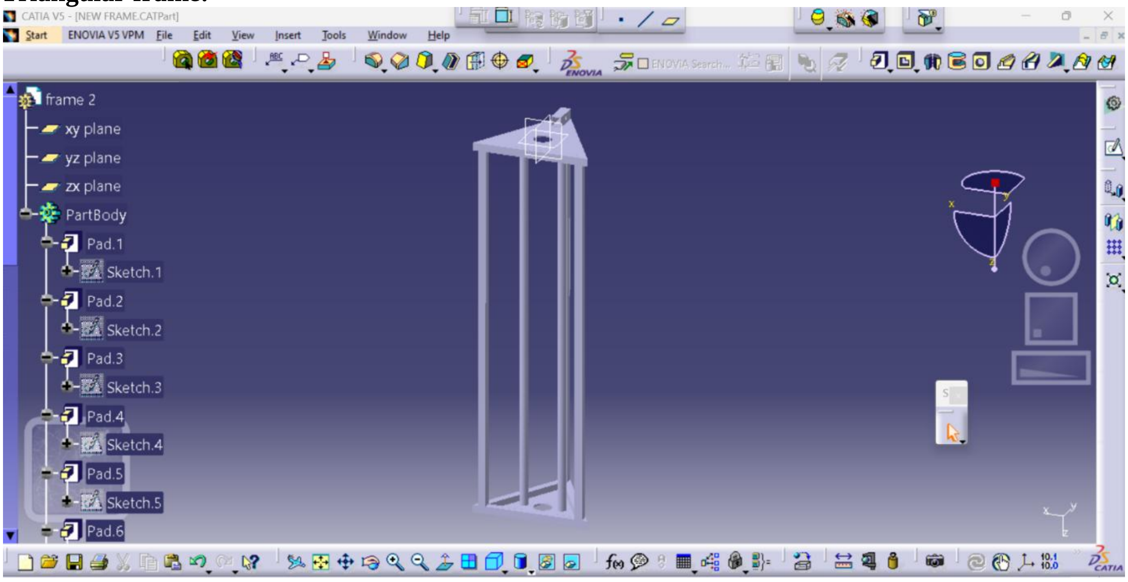

Figure 2.2: Triangular Frame

A triangular frame is a three-dimensional structure that consists of a triangular base and three rectangular sides that connect the corners of the base to a triangular top. The frame is hollow, which means that the interior of the structure is empty. The frame is made of mild steel, which is a low-carbon steel that is easy to weld and shape. It is commonly used in applications that require strength, stability, and load distribution, and is a popular choice due to its many benefits and advantages.

2.4 Dimensions of Triangular frame:

- Height :980mm
- Width :264mm
- Length :300mm
- Triangle plate edge :235mm
- Triangle plate thickness :4mm
- Steel pipes length :972mm

2.5 Brush Frame:

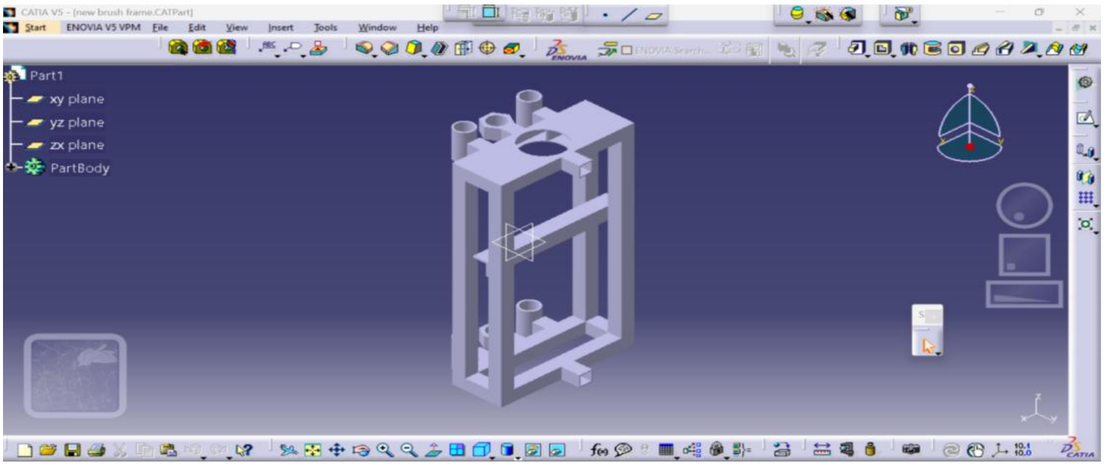

Figure 2.3: Brush frame

A brush frame is a structure made of mild steel that is designed to hold brushes for various cleaning applications. The frame is typically designed in a rectangular or square shape, with a series of holes or slots that allow brushes to be mounted onto the frame. The frame can be used to hold various types of brushes, such as wire brushes, nylon brushes, and other abrasive or non-abrasive brushes.

2.6 Dimensions of Brush frame:

- Height :360mm
- Width :75mm
- Length :205mm
- Motor holding rod length :380mm
- Motor holding rod width :110mm
- Small steel pipes length :380mm

2.7 Final Assembly:

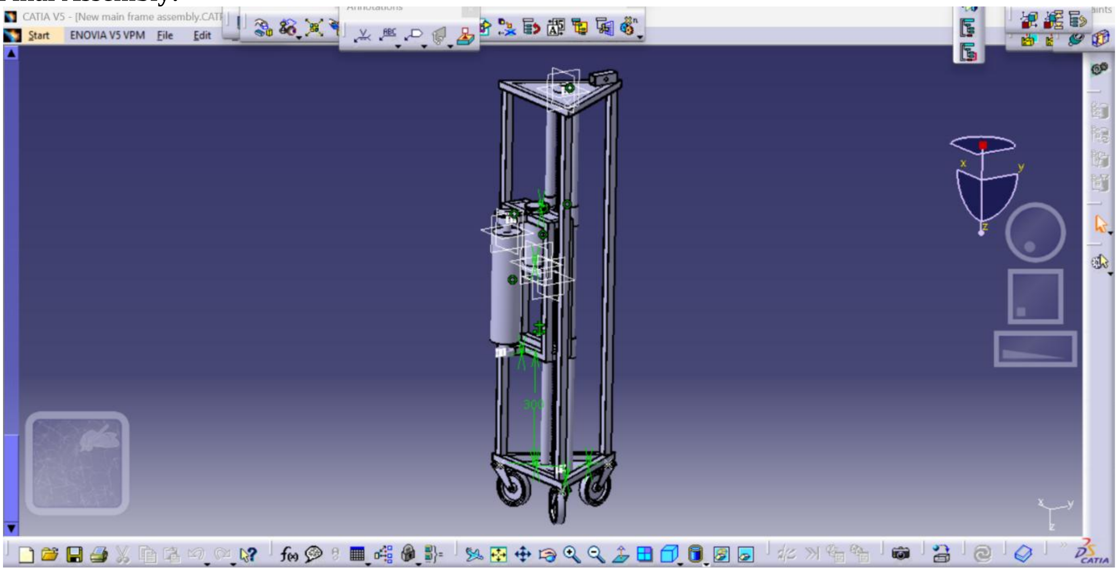

Figure 2.4: Final Assembly

3. Fabrication

3.1 Triangular frame:

Figure 3.1: Triangular frame (MS)

At the initial stage of the fabrication process, the frame structure of the machine has been made using square pipes made of Grade 12 mild steel material. Cut the mild steel tubing to the lengths required in the design using an angle grinder. Start welding the frame once all of the tubing has been cut. To attach the tube at the proper angles and places, use electric arc welding.

A triangle-shaped piece of mild steel with a 4 mm thickness is cut out and welded to the frame. Another identical plate is cut out, and a bearing is welded to the centre of that one as well. A threaded screw with two hexagonal nuts is secured to the bearings at both ends, and steel pipes with a length of 940mm are welded to the vertices of triangular plates. The triangular plates on the left and right sides of the threaded screw are then welded to two stainless steel pipes, each measuring 972 mm in length and outfitted with two sliders.

3.2 Brush frame:

Figure 3.2: Brush frame (MS)

Using an angle grinder, cut the mild steel rectangular tube to the required length by switching out the grinding blade for a cutting blade. To make the frame, cut two sections for a length of 205mm and four parts for a height of 320mm.

A 205mm long rectangular pipe has a 70mm opening. Weld the long pipes to the ends of the rectangular tubing to create a rectangular frame. Welding clamps are used to keep the components in position when welding. To check for squareness, use try square.

Weld the two hexagonal nuts and four hollow circular sliders of 50mm length to the backside of the brush frame with six further pieces of rectangular tubing cut to 20mm length. Weld the two extra pieces of 30mm tubing to the front side of the brush frame in the middle to connect the top and bottom bearings.

3.3 Final Assembly:

Figure 2.3: Final Assembly (MS)

The brush frame is welded to the sliding pipes, which are held together by hexagonal nuts. A DC motor is connected to the threaded screw through spur gears. An extension is welded to one pipe to secure the motor. Another DC motor shaft is welded to a sprocket and connected to a sprocket of a 19mm steel tubing welded to two bearings fitted on the brush frame. Nylon brushes have been mounted to steel pipe.

A chain drive connects two Sprockets. On top of the triangular structure, four holes are drilled with a drilling machine for nut and bolt fastening the water pump. Three caster wheels are welded at the three vertices of the triangle frame's bottom. The overall weight is divided between three wheels. The machine has been painted, and the DC motors and water pump have been wired.

4. Calculations

Weight of machine = 18kg

4.1 Threaded screw:

Mass of the Brush frame	$\mathbf{m_m}$ = 3216.886gm
Mass of two bearings	$\mathbf{m_b}$ = 2×110
	$\mathbf{m_b}$ = 220gm
Mass of two sprockets	$\mathbf{m_s}$ = 2×160
	$\mathbf{m_s}$ = 320gm
Mass of steel pipe	$\mathbf{m_{sp}}$ = 90gm
Mass of two hexagonal nuts	$\mathbf{m_H}$ = 2×72.5
	$\mathbf{m_H}$ = 145gm
Mass of starter motor	$\mathbf{m_{sm}}$ = 850gm
Mass of Threaded screw	$\mathbf{m_{Ls}}$ = 3109.442gm

Total mass $\mathbf{M = m_m + m_b + m_s + m_{sp} + m_H + m_{sm} + m_{Ls}}$

M = 3216.886 + 220 + 320 + 90 + 145 + 850 + 3109.442

M = 7816.328gm = 7.86kg

Force **f** = mass × acceleration = 7.86×9.8 =77.028N

1. Torque required to raise the load $\mathbf{T_r} = \frac{f \times d}{2} \times (\tan(\alpha + \phi))$

$$\frac{77.028 \times 0.024}{2} \times (\tan(30 + 9.6))$$

$\mathbf{T_r}$ = 0.7646N-m

2. Power required to raise the load $\mathbf{P_r} = \frac{2\pi N T_r}{60} = \frac{2\pi \times 300 \times 0.7646}{60} = 24.02\text{W}$

3. Torque required to lower the load $\mathbf{T_l} = \frac{f \times d}{2} \times (\tan(\phi - \alpha))$

$= \frac{77.028 \times 0.024}{2} \times (\tan(30 - 9.6))$

= 0.3437N-m

4. Power required to lower the load $\mathbf{P_l} = \frac{2\pi N T_r}{60} = \frac{2\pi \times 510 \times 0.3437}{60} = 18.35\text{W}$

5. Efficiency of Threaded screw $\boldsymbol{\eta} = \frac{\tan(\alpha)}{\tan(\alpha + \phi)}$

= 0.697×100= 69.7%

6. Torsional shear stress in Threaded screw $\mathbf{s_s} = \frac{16 T_r}{\pi d_c^3}$

$= \frac{16 \times 0.7646}{\pi (0.02)^3} = 486759.478 \frac{\text{N}}{\text{m}^2}$

4.2 Bearing:

Ball bearings with numbering 6204

Hole diameter	**d** = 20mm
Bearing outer diameter	$\mathbf{D_o}$ = 47mm
Width of bearing	**B** = 14mm
Bearing ball radius	**r** = 1.5mm
Static capacity	$\mathbf{C_o}$ = 6375
Dynamic capacity	**C** = 9805
Max. Permissible speed	**N** = 16000rpm

From the setup Axial load on bearing $\mathbf{F_a}$ = 77.028N

We have dynamic capacity $\mathbf{C} = \left(\frac{L}{L_{10}}\right)^{\frac{1}{K}} \times P$............ (1)

Where **k** = 3 for ball bearings

$\mathbf{L_{10}}$=1mr

$\mathbf{L_h}$ = 8000hrs

Since, we use machine only for short period or intermittently and whose breakdown would not have serious consequences.

Equivalent load $\mathbf{P} = (VXF_r + YF_a) \times S$........... (2)

Here, **V** = 1

Since, only inner ring is rotating and outer ring is stationary

Service factor **S** = 1.6

Bearing is used for reciprocating purpose

Now,

$e = \frac{F_a}{C_o} = \frac{77.028}{6375} = 0.012$

Which is less than **e** = 0.022 value, then X =1, Y= 0;

Life of bearing in million revolutions $\mathbf{L} = \left(\frac{C}{P}\right)^k$ mr .... (3)

Life of bearing in hours $\mathbf{L_h} = \frac{L\times10^6}{60\times n}$ .... (4)

Equation (4) can be written as $\mathbf{L} = \frac{L_h\times60\times n}{10^6}$

Here, $\mathbf{L_h}$= 8000; n = 400 rpm

$\mathbf{L} = \frac{8000\times60\times400}{10^6}$ = 192mr

From equation (3),

$\mathbf{L} = \left(\frac{C}{P}\right)^k$ mr

$192 = \left(\frac{9805}{P}\right)^3$

$P^3 = \frac{(9805)^3}{192}$

P^3 = 4909548620

Equivalent load **P** = 1699.601N

From equation (2)

$\mathbf{P} = (VXF_r + YF_a) \times S$

$1699.601 = \big((1 \times 1 \times F_r) + 0 \times (77.028)\big)(1.6)$

$1699.601 = \big((F_r) + 0\big)(1.6)$

$\mathbf{F_r} = \frac{1699.601}{1.6}$

Radial load $\mathbf{F_r}$= 1062.251N

4.3 Gears: Number of teeth for gear 1, $\mathbf{T_1} = 9$

Number of teeth for gear 2, $\mathbf{T_2} = 54$

Number of teeth for gear 3, $\mathbf{T_3} = 14$

Number of teeth for gear 4, $\mathbf{T_4} = 28$

Gear ratio for gear1 and gear2:

$$\frac{T_2}{T_1} = \frac{54}{9} = \frac{6}{1}$$

Gear ratio for gear3 and gear4:

$$\frac{T_4}{T_3} = \frac{28}{14} = \frac{2}{1}$$

Overall Gear Ratio: $\frac{T_2}{T_1} \times \frac{T_4}{T_3} = \frac{12}{1}$

4.4 Chain and sprocket:

Pitch of chain **p**	: 12.7mm
Number of countershaft sprocket teeth **n**	: 14
Number of Rear sprocket teeth **N**	: 14
Centre to centre of both sprockets' **c**	: 90mm
Chain module **m**	: 7.0787mm

We have,

Pitch circle diameter of sprocket $\mathbf{d_p} = \frac{p}{\sin\left(\frac{180}{T}\right)} = \frac{12.7}{\sin\left(\frac{180}{14}\right)} = 57.07$mm

Pitch circle radius of sprocket **r** = 28.535mm

Number of links = 28

Length of chain = **p×K**…………… (5)

Where, **p** = $2\times r\times \sin\left(\frac{180}{T_2}\right) = 2\times 28.535\times \sin\left(\frac{180}{14}\right) = 12.699$mm

Multiplying factor, $\mathbf{K} = \frac{(\mathbf{T_1}+\mathbf{T_2})}{\mathbf{2}} + 2m + \frac{\left[\mathrm{cosec}\left(\frac{180}{T_1}\right) - \mathrm{cosec}\left(\frac{180}{T_2}\right)\right]^2}{4m}$

$= \frac{(14+14)}{2} + 2\times 7.0787 + \frac{\left[\mathrm{cosec}\left(\frac{180}{14}\right) - \mathrm{cosec}\left(\frac{180}{14}\right)\right]^2}{4\times 7.0787}$

$= 14 + 14.1574 + 0 = 28.1574$

From equation (5),

Length of chain = **p×K**=12.699×28.1574

Length of chain = 357.5989mm

Sprocket reduction ratio = $\frac{T_2}{T_1} = \frac{14}{14} = 1$

Rated power of motor = 0.3kW = 300W

Speed of drive sprocket $\mathbf{N_1}$ = 2639 rpm

Speed of driven sprocket $\mathbf{N_2}$ = 2639 rpm

Velocity ratio = $\frac{\mathbf{N_1}}{\mathbf{N_2}} = \frac{2639}{2639} = 1$

Load factor $\mathbf{k_1}$ = 1; Lubrication factor $\mathbf{k_2}$= 1.5;Rating factor $\mathbf{k_3}$=1

Service factor $\mathbf{k_s} = \mathbf{k_1} \times \mathbf{k_2} \times \mathbf{k_3}$= 1×1.5×1 = 1.5

Design power = Rated power ×Service factor = 300×1.5 = 450W

4.5 Force of Brush:

Rated power of motor $\mathbf{P_m}$= 350W; $\mathbf{N_c}$=1770rpm

$$\mathbf{P_m} = \frac{\mathbf{2\pi N_c T}}{\mathbf{60}};\ \mathbf{P_m} = \frac{2\pi\times 1770\times T}{60}$$

$$T = \frac{\mathbf{350}\times 60}{2\pi\times 1770} = 1.88 \text{ N-m}$$

$$T = F\times r;\ F = \frac{1.888}{0.0365} = 51.7 \text{ N}$$

5. Conclusion

The proposed design of a semi-automatic overhead water tank cleaning machine is constructed as a prototype for cleaning the tank, as the height of the tank increases, the size of the lead screw gets increased, and also the base structure is being strengthened by providing suitable ribs for the support members. By implementing this type of system, the requirement of working labour in such risky areas will be reduced, and work will also be completed in less time. Thus, the dangerous accidents occurring during these operations can be reduced.

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