DESIGN, ANALYSIS & FABRICATION OF PORTABLE CAR WASH TROLLEY

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ABSTRACT

In industries, there are large numbers of huge machines, being used for various purposes. These machines are taken for maintenance according to its maintenance period. These machines are washed using high pressure washer to remove the dirt, grease or any other lubricants or rust from its surface before they are being worked on for maintenance. These pressure washers removes large amount of dirt.

Washing the buses in our institute is a tedious job for the driver. Nowadays there are pressure washers available which are used for domestic purpose. The technique used in this pressure washer will be used to fabricate a portable car wash which can be used to wash the buses of the institute. A suitable pump and motor unit is selected and along with a tank are mounted on a trolley with wheels so that the whole machine becomes portable to be carried anywhere.

***Keywords: Nozzle, Plunger pump, portable, pressure, trolley*.**

I. INTRODUCTION

As the weather gets nicer every day, and we clean our house and care for our lawns; it's only natural that we want to give our ride a nice wash. Just drive past any car wash on a weekend and you'll see cars lined up waiting for their turn in the wash tunnel.

A pressure washer is a high pressure mechanical sprayer used to remove loose paint, mold, grime, dust, mud, and dirt from surfaces and objects such as buildings, vehicles and concrete surfaces. The volume of a pressure washer is expressed in gallons or litres per minute, often designed into the pump and not variable. The pressure, expressed in pounds per square inch, pascals, or bar, is designed into the pump but can be varied by adjusting the unloader valve. Machines that produce pressures from 750 to 30,000 psi (5 to 200 MPa) or more are available. Car wash is a $24 billion industry according to international car wash association.

The basic pressure washer consists of:

- A motor, such as electric, internal combustion, pneumatic or hydraulic, that drives a high pressure water pump
- A high-pressure hose
- Trigger gun-style switch

Just as a garden hose nozzle is used to increase the velocity of water, a pressure washer creates high pressure and velocity. The water supply must be adequate for the machine, as water starvation leads to cavitation causing damage to the pump elements.

Different types of nozzle are available for different application. Some nozzles create a water jet that is in a triangular plane (fan pattern), others emit a thin jet of water that spirals around rapidly (cone pattern). Nozzles that deliver a higher flow rate, lower the output pressure. Most nozzles attach directly to the trigger gun.

Some washers, with an appropriate nozzle, allow detergent to be introduced into the water stream, assisting in the cleaning process. Two types of chemical injectors are available — a high-pressure injector that introduces the chemical after the water leaves the pump (a downstream injector) and a low-pressure injector that introduces the chemical before water enters the pump (an upstream injector).

Washers are dangerous tools and should be operated with due regard to safety instructions. The water pressure near the nozzle is powerful enough to strip flesh from bone. Particles in the water supply are ejected from the nozzle at great velocities. The cleaning process can propel objects dislodged from the surface being cleaned, also at great velocities. Pressure washers have a tendency to break up tarmac if aimed directly at it, due to high pressure water entering cracks and voids in the surface.

Most consumer washers are electric or petrol-powered. The electric ones plug into a normal outlet, use cold tap water and typically deliver pressure up to about 2,000 psi (140 bar). Petrol washers can deliver twice that pressure, but due to the hazardous nature of the engine exhaust they are unsuitable for enclosed or indoor areas. Some models can generate hot water, which can be ideal for loosening and removing oil and grease [2].

The fabrication of a Portable High Pressure Washer is done by mounting a motor and pump assembly of specific requirement on a suitably designed mobile trolley. A jet producing nozzle is connected to a pump with the help of a suitable hose. This washer can be used to wash the underbody of the vehicle due to its high velocity jet, wash the greasy walls of the workshops, etc.

Car washes fall into five categories:

- Self service - An open bay (the area that the car sits inside) is typically used in these systems. Self-service systems have a pressure sprayer, and sometimes a foaming brush, that is connected to a large central pump. The sprayer has a coin-operated dial system to select the option you want, such as "soap," "rinse" and "wax." A timer shuts the water off after a certain period of time, at which point you must put in more coins if you want more water.
- Exterior rollover - A system that is growing in popularity, exterior rollover car washes are automated systems where you drive your car inside the bay. Once your car is in the correct position, a signal informs you to stop. At that point, the car-wash equipment moves over your car on a track, performing a specific function, such as applying soap or rinsing, with each pass. Exterior rollover systems are very common atgas stations, where the price is often discounted in conjunction with buying a tank of gas.
- Exterior only - This automated system is popular in the northeastern part of the United States, but can be found all over the world. You drive your car into the entrance of a long, tunnel-like bay. The front tire, usually

on the driver's side, is positioned on a special conveyor belt, and you put the car in neutral. The conveyor belt guides the car through the bay, where the car goes past several pieces of equipment, each with a specific purpose.

- Full service - A modification of the exterior-only system, full service uses the same conveyor-belt-based automated system. The difference is that the interior is manually cleaned by attendants, and some exterior services, such as hand-drying and wheel-cleaning are available.

- Detail shop - A detail shop may hand wash or use an automated system to wash the car. Then, attendants completely clean and polish the car, normally applying wax and using a tool called a buffer to remove the wax and polish the car. Detail shops are often able to remove dull paint and small scratches,steam clean carpets and seats, brighten chrome, remove tar and perform a variety of other services.

1.1 Home Car Wash

Things you need for the home car wash before your start include:

- 2 bucket
- Soft water or rainwater - avoid dam or bore water
- Shade - direct sunlight will dry the car too quickly and leave spots
- Warm soapy water - PH neutral shampoo
- Sheeps wool wash mitt - kinder and easier to use than a sponge

1.1.1 Washing Procedure

Wheels - Start with the wheels. This is because the wheels of a car will be dirtier than the rest with potentially large bits of dirt that can scratch the paint of a car. Be sure to use a different water bucket, wash mitt or sponge for the wheels than the rest of the car as not to damage the body work. To clean in small holes in the wheels use a toothbrush to easy reach hidden areas. Rinse thoroughly with a hose and be extra careful not to mix your wheel cleaning equipment with you regular washing equipment.

Rinse - It is important that you rinse your car thoroughly before starting to wash; this is to remove any harmful dirt and grit that can scratch the paint finish of the car. Top to bottom, spray from the roof down. Make sure to spray underneath the windscreen wipers as extra dirt may collect there.

Separate Buckets - It’s best to have a separate bucket to use as a rinse bucket where possible using grit guard. The guard and the separate bucket of water allow for all of the dirt, grit and contaminants to remain in the separate bucket away from the clean soapy water. By keeping separate buckets it ensure that the dirty water will not contaminate the clean water and ruin the over finish of the car wash.

Wash and Rinse - Again it is important to wash and rinse from top to bottom gently. When washing tough spots such as droppings or sap, apply concentrated soap to the area and gently rub to avoid scratching the paint. If you have any dents or crack in the paint be sure to pay attention to these places as there may be a buildup of dirt.

When rinsing the car start from the roof to ensure that the water droplets catch all the soap suds and rinse them away to the ground.

Dry - Use car washing towel rather than a chamis, most of these will hold more than their weight in water and are super absorbent. Dry the bodywork of the car using small circles to avoid streaking. The best way to tell if your windows are streak free is to dry the outside horizontally and the inside vertically this way if there are extra marks you can tell which side they're on.

1.2 Objectives of the Project

- To build a Portable Car Washer, which can be moved easily to any location?
- To get a high pressure jet of water to remove the dirt, grease or any other lubricants or rust from the surface before they are being worked on for maintenance.
- To fabricate the trolley for the portable car washer, considering the weight & dimensions for different parts.

II. LITERATURE REVIEW

People have found ways to wash their cars ever since cars were invented. They either washed it themselves at home, or paid someone else to wash it by hand. Then, in 1914, two Detroit men opened the first car wash business, which they called the "Automated Laundry", but it wasn't really automated. It was basically a pail and sponge type of operation where the cars were pushed manually through an assembly-line-like tunnel, where one attendant would soap the car as it went past, another would rinse, and a third would dry. After pushing a few cars through, the attendants got pretty tired.

The first "automatic" conveyor car wash was opened in Hollywood, California in 1940. Instead of manually pushing the cars through, this car wash had a winch system that hooked to the bumper and pulled the car through as men splashed away in the tunnel, soaping, scrubbing, wiping, and drying cars as they came through. By 1946, a man named Thomas Simpson is credited with inventing the first semiautomatic car wash system that took most of the manual labor out of the tunnel [8]. It had a conveyor belt that hooked to the bumper of automobiles, an overhead water sprinkler with three sets of manually operated brushes, and a 50 HP air blower to help dry the car.

Then, in 1951, Archie, Dean and Eldon Anderson got the great idea to fully automate their car wash. As the story goes, the Anderson clan invented the completely hands-free automatic car wash in Seattle. Cars would be pulled through the tunnel and machines sprayed soap on them, big brushes scrubbed them, nozzles rinsed them, and giant blowers dried them. Needless to say, this was a big hit! Soon, many other car wash owners were installing automatic equipment in their car wash business

A lot happened to the car wash industry in 1955, Dan Hanna being inspired by the Detroit carwashes opened his own automated car wash (Rub-a-Dub) in Oregon. By 1957 Hanna Enterprises had 31 carwashes in America.

Around the same time in 1955 car wash professionals formed the Automatic Car Wash Association (ACWA) later being recognized worldwide, being re named to the International Carwash Association (ICA).

Fig. 2.1 Fully Mechanized Car washing

Through the 1960's, fully mechanized car washing systems were being installed across America. With conveyor car wash equipment advancing, the 60's saw inventions such as recirculating water systems, soft cloth friction washing, roller on demand conveyor, and wraparound brush. By the late 60's car washes were becoming a prominent industry worldwide with car washes being installed in many countries, including Japan.

The 70's saw a downturn in business for car washes with the global economy weakening, However car washes managed to stay alive with innovative inventions.

The 90's saw the global boom of the car wash with new technologies expanding across the Far East, China, Russia and Eastern Europe. With Latin America and Southeast also amongst the growth Hanna Enterprises now (Hanna-Sherman International) were the biggest global car washing factory in the world.

The car wash evolved into weekly trip for many people predominantly on a Saturday with hand car washes developing into charity fund raisers and weekend jobs for kids. The ICA estimates that there around 22,000 car washes worldwide employing about 500,000 people.

Today's car washes are literally cleaning machines. They not only wash all five sides of the car at once, but scrub tires and wash the undercarriage as well. They are more Eco-friendly, with milder soaps and lower water and electric requirements. Many of the newer car washes even have express tunnels that get your car through quickly, all of which leads to more clean cars and happier car owners.

III. COMPONENTS

The following components are part of our project. They include;

- Pump - Swash Plate Type 3 Piston Pump
- Trolley
- Water Tank
- Hose
- Trigger Gun
- Nozzle

The above components are assembled together to make the portable car wash. These components are explained below.

3.1 Pump

A pump is a device that moves fluids (liquids or gases), or sometimes slurries, by mechanical action. Pumps can be classified into three major groups according to the method they use to move the fluid: direct lift, displacement, and gravity pumps.

Pumps operate by some mechanism (typically reciprocating or rotary), and consume energy to perform mechanical work by moving the fluid. Pumps operate via many energy sources, including manual operation, electricity, engines, or wind power, come in many sizes, from microscopic for use in medical applications to large industrial pumps. Pumps that move liquid by mechanical action are called hydraulic pumps.

3.1.1 Hydraulic Pump

Hydraulic pumps are used in hydraulic drive systems and can be hydrostatic or hydrodynamic. Hydrostatic pumps are positive displacement pumps while hydrodynamic pumps can be fixed displacement pumps, in which the displacement (flow through the pump per rotation of the pump) cannot be adjusted, or variable displacement pumps, which have a more complicated construction that allows the displacement to be adjusted [4].

Hydraulic pump types

- Gear pumps
- Rotary vane pumps
- Screw pumps
- Bent axis pumps
- In-line Axial piston pumps, swashplate principle
- Radial piston pumps

3.1.2 Swash Plate Type 3 Plunger Pump

Swash Plate Type 3 Piston Pump, an in-line axial piston pump is a positive displacement pump that has a number of pistons in a circular array within a cylinder block. An axial piston pump has a number of pistons (usually an odd number) arranged in a circular array within a housing which is commonly referred to as a cylinder block, rotor or barrel. This cylinder block is driven to rotate about its axis of symmetry by an integral shaft that is, more or less, aligned with the pumping pistons [1].

One end of the cylinder block is convex and wears against a mating surface on a stationary valve plate. The inlet and outlet fluid of the pump pass through different parts of the sliding interface between the cylinder block and valve plate. The valve plate has two semi-circular ports that allow inlet of the operating fluid and exhaust of the outlet fluid respectively [5].

The pumping pistons protrude from the opposite end of the cylinder block. There are numerous configurations used for the exposed ends of the pistons but in all cases they bear against a cam. In variable displacement units, the cam is movable and commonly referred to as a swash plate, yoke or hanger. For conceptual purposes, the cam can be represented by a plane, the orientation of which, in combination with shaft rotation, provides the cam action that leads to piston reciprocation and thus pumping. The angle between a vector normal to the cam plane and the cylinder block axis of rotation, called the cam angle, is one variable that determines the displacement of the pump or the amount of fluid pumped per shaft revolution. Variable displacement units have the ability to vary the cam angle during operation whereas fixed displacement units do not.

As the cylinder block rotates, the exposed ends of the pistons are constrained to follow the surface of the cam plane. Since the cam plane is at an angle to the axis of rotation, the pistons must reciprocate axially as they precess about the cylinder block axis. The axial motion of the pistons is sinusoidal. During the rising portion of the piston's reciprocation cycle, the piston moves toward the valve plate. Also, during this time, the fluid trapped between the buried end of the piston and the valve plate is vented to the pump's discharge port through one of the valve plate's semi-circular ports - the discharge port. As the piston moves toward the valve plate, fluid is pushed or displaced through the discharge port of the valve plate.

When the piston is at the top of the reciprocation cycle (commonly referred to as top-dead-center or just TDC), the connection between the trapped fluid chamber and the pump's discharge port is closed. Shortly thereafter, that same chamber becomes open to the pump's inlet port. As the piston continues to precess about the cylinder block axis, it moves away from the valve plate thereby increasing the volume of the trapped chamber. As this occurs, fluid enters the chamber from the pump's inlet to fill the void. This process continues until the piston reaches the bottom of the reciprocation cycle commonly referred to as bottom-dead-center or BDC. At BDC, the connection between the pumping chamber and inlet port is closed. Shortly thereafter, the chamber becomes open to the discharge port again and the pumping cycle starts over.

In a variable displacement unit, if the vector normal to the cam plane (swash plate) is set parallel to the axis of rotation, there is no movement of the pistons in their cylinders. Thus there is no output. Movement of the swash plate controls pump output from zero to maximum.

A swash plate is a device used in mechanical engineering to translate the motion of a rotating shaft into reciprocating motion, or to translate a reciprocating motion into a rotating one to replace the crankshaft in pump designs. A swash plate consists of a disk attached to a shaft. If the disk were aligned perpendicular to the shaft, then rotating the shaft would merely turn the disk with no reciprocating (or swash plate) effect. But instead the disk is mounted at an oblique angle, which causes its edge to appear to describe a path that oscillates along the shaft's length as observed from a non-rotating point of view away from the shaft. The greater the disk's angle to the shaft, the more pronounced is this apparent linear motion. The apparent linear motion can be turned into an actual linear motion by means of a follower that does not turn with the swash plate but presses against one of the disk's two surfaces near its circumference. The device has many similarities to the cam. The picture of the pump can be seen below.

Fig. 3.1.1: Swash Plate Type 3 Plunger Pump

The pump is coupled with a 240V 50 Hz AC motor with a power of 1 hp. An electric motor is an electric machine that converts electrical energy into Mechanical energy. Most electric motors operate through the interaction between an electric motor's magnetic field and winding currents to generate force within the motor. Electric motors can be powered by direct current (DC) sources, such as from batteries, motor vehicles or rectifiers, or by alternating current (AC) sources, such as from the power grid, inverters or generators.

3.2 Trolley

The trolley used in this project is an L-shaped box-moving handcart with handles at one end, wheels at the base, with a small ledge to set objects on, flat against the floor when the hand-truck is upright. The objects to be moved are allowed to rest on the ledge. Then the truck and object are tilted backward until the weight is balanced over the large wheels, making otherwise bulky and heavy objects easier to move. The whole assembly of portable car wash is mounted on the trolley. The trolley consists of a main frame and an extension to it. The pump will be mounted on the front extension and the tank will be placed on the main frame. The Model of the trolley is shown in the figure;

Fig. 3.2.1: Trolley

The width of the trolley is 370 mm and the length of the trolley is 370 mm and the height of the trolley is 60 mm. The trolley frames is made using angle channels and its material is Mild Steel. The main frame is made using the angle of outer sides 50 mm and thickness 7 mm. The extended frame is made up of angle channels of sides 40 mm each and the thickness 5 mm. The two pillars of height 320 mm are welded at the front of main frame to which the pump will be clamped. Another two pillars of height 690 mm are welded to which a handle is fixed which will be used to move the trolley.

3.3 Water Tank

A water tank is a container for storing water. Water tank parameters include the general design of the tank, and choice of construction materials. By design a water tank or container should do no harm to the water.

A water tank of capacity 35 liters is used to store the water. This water will be used by the pump to spray it via nozzle. An outlet hole is drilled to the tank to which a tank nipple is placed. The picture of the tank is shown in the figure below;

Fig. 3.3.1: Tank

The pipe is connected to the tank nipple which then again forms the inlet to the pump. The tank is made up of plastic material. Its thickness is 3 mm. When fully filled to 35 liters, its weight that acts on the trolley is around 35 kg.

3.4 Hose

A hose is a flexible hollow tube designed to carry fluids from one location to another. Hoses are also sometimes called pipes (the word pipe usually refers to a rigid tube, whereas a hose is usually a flexible one), or more generally tubing. The shape of a hose is usually cylindrical.

Hose design is based on a combination of application and performance. Common factors are Size, Pressure Rating, Weight, Length, Straight hose or Coil hose and Chemical Compatibility.

To take the water from the pump to the area of application a hose is required. The hose should sustain the pressure produced inside it by the action of pump and the nozzle. The hose used is of 5 mm diameter and its length is 3.5 m. It is connected to the outlet of the tank and its other end to the trigger gun.

3.5 Trigger Gun

In most pressure cleaning equipment, the pump motor is turned on and off at the machine. The operator, however, may be cleaning as far as 100 feet away. When he wants to stop spraying water he needs a way to stop water flow without walking back to the machine. The trigger gun and pressure switch/unloader valve provide that kind of control literally at the operator's fingertips. The trigger gun used is shown in the picture on the next page.

Fig. 3.5.1: Trigger Gun

A trigger spray gun is nothing more than a valve that closes when the trigger is released [6]. Trigger guns are fairly simple mechanisms designed around a trigger-operated switch. It prevents the gun from getting out of control and causing damage or injury. It also saves water and fuel by switching off the motor once trigger is released.

The trigger gun is connected between the hose and the nozzle. Its main function is to start or stop the flow. The hose is connected to the trigger gun, from which the water is passed to the nozzle. The trigger gun is manufacture by BOSCH. It is able to sustain the maximum pressure upto 130 bar. When the trigger switch is pressed the water is pumped out and sprayed through nozzle. When the trigger is released the flow is stopped. This develops back pressure in the pump. Due to this a back pressure switch is provided in the pump which stops the motor when the pressure is built up in the pump.

3.6 Nozzle

A nozzle is a device designed to control the direction or characteristics of a fluid flow as it exits (or enters) an enclosed chamber or pipe.

A nozzle is often a pipe or tube of varying cross sectional area and it can be used to direct or modify the flow of a fluid (liquid or gas) [7]. Nozzles are frequently used to control the rate of flow, speed, direction, mass, shape, and/or the pressure of the stream that emerges from them.

Types

- Jet
- Propelling
- Magnetic
- Spray
- Vacuum
- Shaping

3.6.1 Adjustable Nozzle

Adjustable nozzles are basically a type of jet nozzle which allows variable pressure or variable spray pattern adjusted at the nozzle. Instead of several standard nozzles on a rotating mount, the true adjustable nozzle is designed with moving parts, which allow orifice restriction or enlargement to change output pressure or variable spray deflection to change the nozzle spray pattern.

Fig. 3.6.1: Adjustable nozzle

Some adjustable nozzles are designed for both adjustable pressure and spray pattern. Since these nozzles have moving parts, they are more expensive and more subject to wear than standard nozzles. Adjustable nozzles are usually supplied with equipment producing volumes and pressures in the lower ranges. For example, many hobby and small cold-water machines come with an adjustable nozzle to allow for low-pressure chemical injection. The diameter of the nozzle used is 1 mm and the angle is 1°.

3.6.2 Nozzle performance factors

- Liquid properties

Almost all drop size data supplied by nozzle manufacturers are based on spraying water under laboratory conditions, 70 °F (21 °C). The effect of liquid properties should be understood and accounted for when selecting a nozzle for a process that is drop size sensitive.

- Temperature

Liquid temperature changes do not directly affect nozzle performance, but can affect viscosity, surface tension, and specific gravity, which can then influence spray nozzle performance.

- Specific gravity

Specific gravity is the ratio of the mass of a given volume of liquid to the mass of the same volume of water. In spraying, the main effect of the specific gravity Sg of a liquid other than water is on the capacity of the spray nozzle. All vendor-supplied performance data for nozzles are based on spraying water. To determine the volumetric flow rate Q, of a liquid other than water the following equation should be used.

$$Q_f = Q_{water}\sqrt{\frac{1}{Sg}} \quad \text{….. Eq 3.6.2.1}$$

- Viscosity

Dynamic viscosity is defined as the property of a liquid that resists change in the shape or arrangement of its elements during flow. Liquid viscosity primarily affects spray pattern formation and drop size. Liquids with a high viscosity require a higher minimum pressure to begin spray pattern formation and yield narrower spray angles compared to water.

- Surface tension

The surface tension of a liquid tends to assume the smallest possible size, acting as a membrane under tension. Any portion of the liquid surface exerts a tension upon adjacent portions or upon other objects that it contacts. This force is in the plane of the surface, and its amount per unit of length is surface tension. The value for water is about 0.073 N/m at 21 °C. The main effects of surface tension are on minimum operating pressure, spray angle, and drop size. Surface tension is more apparent at low operating pressures. A higher surface tension reduces the spray angle, particularly on hollow cone nozzles. Low surface tensions can allow nozzles to be operated at lower pressures.

- Nozzle wear

Nozzle wear is indicated by an increase in nozzle capacity and by a change in the spray pattern, in which the distribution (uniformity of spray pattern) deteriorates and increases drop size. Choice of a wear resistant material of construction increases nozzle life. Because many single fluid nozzles are used to meter flows, worn nozzles result in excessive liquid usage.

- Material of construction

The material of construction is selected based on the fluid properties of the liquid that is to be sprayed and the environment surrounding the nozzle. Spray nozzles are most commonly fabricated from metals, such as brass, Stainless steel, and nickel alloys, but plastics such as PTFE and PVC and ceramics (alumina and silicon carbide) are also used. Several factors must be considered, including erosive wear, chemical attack, and the effects of high temperature.

- Orifice diameter

Orifice diameter (the diameter of the hole in the discharge side of the nozzle) determines the pressure produced at a particular flow. A smaller orifice will produce a higher pressure or psi figure at a specific flow or gpm than a larger orifice. Pressure represents the amount of force needed to move water through the nozzle orifice

- Distance From The Surface Being Cleaned

How far the spray nozzle is from the surface being cleaned makes a major difference in water impact. The greater this distance, the less impact water will have. However, the greater distance increases the amount of area covered by the spray. The operator can easily adjust the spraying distance to suit different types of cleaning applications and perform his job most efficiently.

When water is sprayed into the atmosphere from the nozzle it immediately begins losing speed, and consequently force, due to air friction and other factors. Holding the spray nozzle very close to the surface will give more impact on hard-to-clean areas.

Holding the spray nozzle four or five inches away will be adequate for most moderate soils. The larger the equipment's output, the greater the distance the water spray is capable of traveling while still retaining adequate cleaning ability.

- Theoretical Spread and Spray Angle Coverage

Although nozzle spray patterns are expressed in degrees of spread, these figures are not precisely accurate as the distance between the cleaning surface and the nozzle increases, which is why the terms theoretical spread or theoretical coverage are used. Theoretical spray angles indicate approximate spray coverage's based on water velocity. In actual use the spray angle varies with distance.

- Nozzle Protectors

Most nozzle wear is due to external abuse. Concrete is probably the great nozzle killer. Equipment operators will bang the nozzle against the concrete, drag it across concrete or even use the lance and gun nozzle down as a crutch or cane. It's very easy for the operator to develop a habit of leaning on the gun and lance when taking a break. Not only will this wear down the nozzle, resulting in spray pattern deterioration, the nozzle can easily become clogged. Nozzle protectors are available. Usually made of rubber, these devices should extend past the nozzle a little and can prolong nozzle life. The protectors, however, will have to be replaced on a regular basis.

IV. CALCULATIONS

4.1 Hydraulic Power

$$\text{Power} = \frac{Q \times p}{1715} \qquad \text{….. Eq 4.1.1}$$

Where Q= Flow rate in Gallons per minute

P= Pressure of water in psi

Now, 1 Gallon per minute = 3.78 Liters per minute

1 psi = 0.0689 bar

The flow rate of the pump is 4.5 lpm and power is 1 hp.

$$1 = \frac{1.18877 \times P}{1715}$$

$$P = 1442.66 \text{ psi}$$

$$= 99.399 \text{ bar}$$

The maximum pressure developed by the pump is approximately 100 bar.

4.2 Velocity of the jet

$Q = A \times V$ …… Eq 4.2.1

Where Q = discharge in m^3/sec

A = Area of the nozzle exit in m^2

V = Velocity of jet in m/sec

Now, $A = \pi d^2/4$

Where d = diameter of nozzle = 1 mm.

$A = 7.88 \times 10^{-7}\ m^2$

Discharge of the pump is 4.5 lpm i. e. $7.5 \times 10^{-5}\ m^3$/sec

Now, V = Q/A

$= 7.5 \times 10^{-5} / 7.854 \times 10^{-7}$

V = 95.49 m/sec

V. MODELLING AND ANALYSIS OF TROLLEY

5.1 Modeling of Trolley

Major platform on which the components will be mounted is a trolley. To check whether it is safe to handle the weights of the pump and the tank we are modeling the trolley using software available for modeling and then the trolley is analyzed for load conditions.

The modeling is carried out using SOLID EDGE ST5 from the 2D drawings, and the models are further imported for meshing of the models. The SOLID EDGE was used as the modeling software and from the 2D drawings of the trolley, the 3D model was generated. The models are shown below in the figure 5.1.1

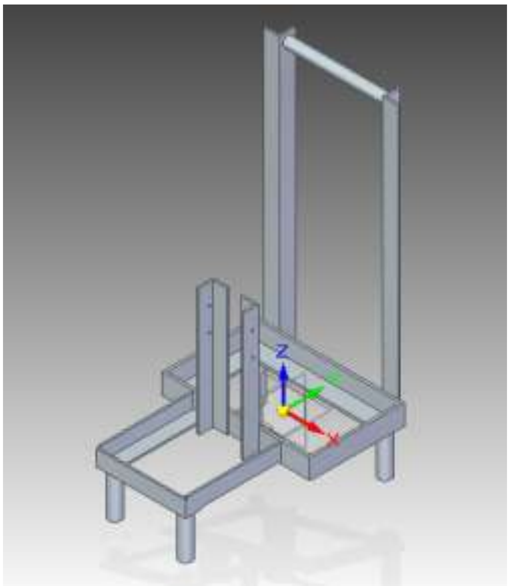


Fig. 5.1.1: Trolley 3D Model.

The trolley comprises mainly:

- Main frame

- Extension for mounting of pump
- Angle pillars to clamp the pump

5.2 Finite Element Analysis

In the field of Engineering Design we come across many complex problems, the Mathematical formulation of which is tedious and usually not possible by analytical methods. At such instants we resort to the use of numerical techniques. Here lies the importance of FEA, which is a very powerful tool for getting the numerical solution of a wide range of engineering problems. The basic concept is that a body or structure may be divided into smaller elements of finite dimensions called as "Finite Elements". The original body or structure is then considered as an assemblage of these elements connected at a finite number of joints called as "Nodes" or "Nodal Points". The properties of the elements are formulated and combined to obtain the properties of the entire body.

The equations of equilibrium for the entire structure or body are then obtained by combining the equilibrium equations of each element such that the continuity is ensured at each node. The necessary boundary conditions are then imposed and the equations of equilibrium are solved to obtain the required variables such as stress, strain, temperature distribution or Velocity flow depending on the application.

Thus instead of solving the problem for the entire structure or body in one operation, in the method the attention is mainly devoted to the formulation of properties of the constituent elements. A common procedure is adopted for combining the elements, solution of equations and evaluation of the required variables in all fields. Thus the modular structure of the method is well exploited in various disciplines of engineering.

5.3 Stepwise Approach for FEA and Underlying Principle

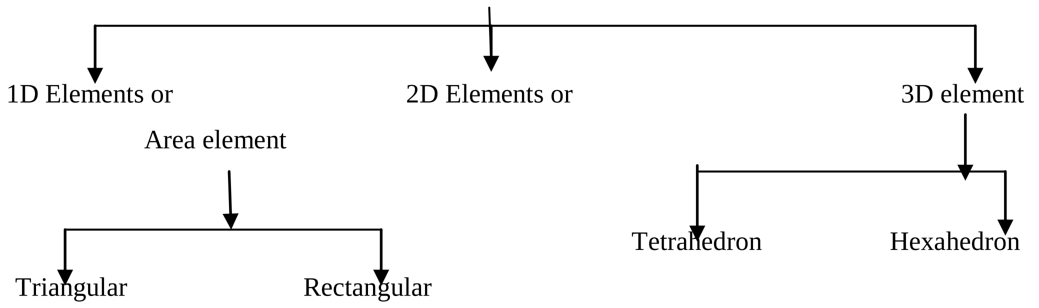
The most fundamental underlying concept of finite element analysis is the piecewise approximation of solution of a known geometry for which the characteristics are well established. Thus, the first requirement of FEA approach is discretization of the physical domain for which appropriate type of element is required to be selected.

5.3.1 Domain discretization for a field Problem

This is also referred to as finite mesh generation step. Here the domain of problem addressed is divided into a number of geometrically simple sub domains termed as finite elements with certain nodal points being associated with each element. In the process, data concerning nodal coordinates, node numbers, element numbers and connectivity is generated. Following figure provides examples of elements employed in one, two and three dimensions.

FEA CLASSIFICATION

Various Element Geometries



5.3.2 Discretization of Problem

Element equation: the next step is to develop equations to approximate the solution for each element. This involves two steps.

First, we choose an appropriate function with unknown coefficients that will be used to approximate the solution.

Second is evaluating the coefficients so that the function approximates the solution in an optimal fashion.

5.3.3 Optimal Fit

The element equation is an approximate solution. In this step the attempt to minimize the error of fitting the solution over the element domain is made using celebrated methods like direct approach method, the method of weighted residuals, and the variational approach.

5.3.4 Assembly to obtain global system of equation from element equations

After the individual element equations are derived, they must be linked together or assembled to characterize the unified behavior of the entire system. The assembly process is governed by the concept of continuity. That is, the solutions for contiguous elements are matched so that the unknown values at their common nodes are equivalent. Thus, the total solution will be continuous.

5.3.5 Boundary Conditions

The nodes on the boundary of domain subjected to known conditions are considered to take effect in assembled set of equations.

5.3.6 Solution

Now the number of unknowns in the equations' set is equal to number of equations, which could be solved using Gaussian elimination equation or other suitable algorithms.

5.3.7 Post Processing

Upon obtaining a solution it can be output in tabular form or displayed graphically.

5.4 Analysis

The model is analyzed using the software ANSYS 14.0.

5.4.1 Meshing

The meshing of the model is done using ANSYS 14.0 Workbench. The meshed model is further used for various analysis. The meshed model is shown in the figure below;

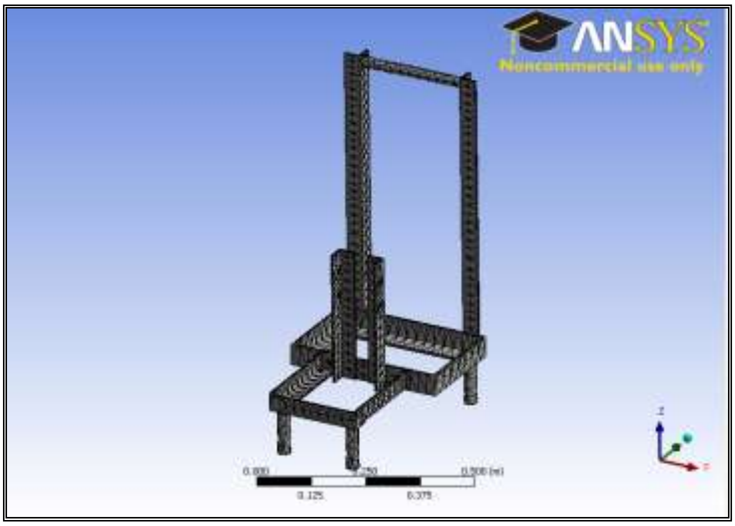


Fig. 5.4.1: Meshed Model of Trolley.

The table 5.4.1 shows the mesh information of the trolley

No. of Elements	6463
No. of nodes	14639

Table 5.4.1: Mesh information of Trolley

5.5 Static Structural Analysis of Trolley

The static structural analysis is carried out for static loadings on the trolley.

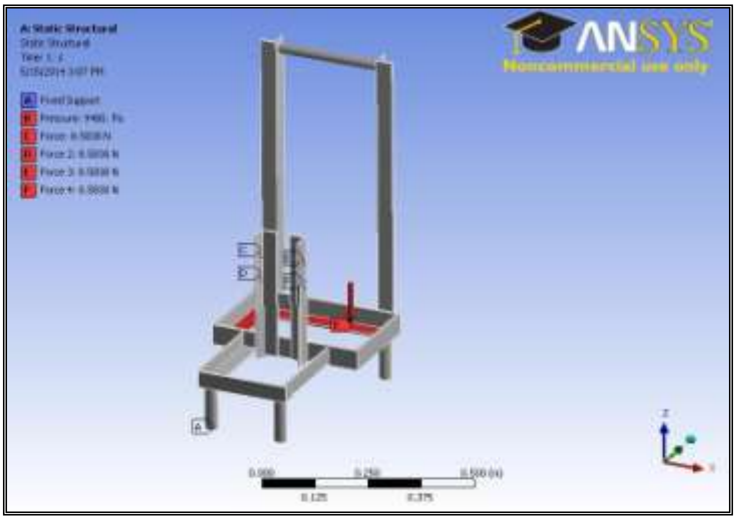
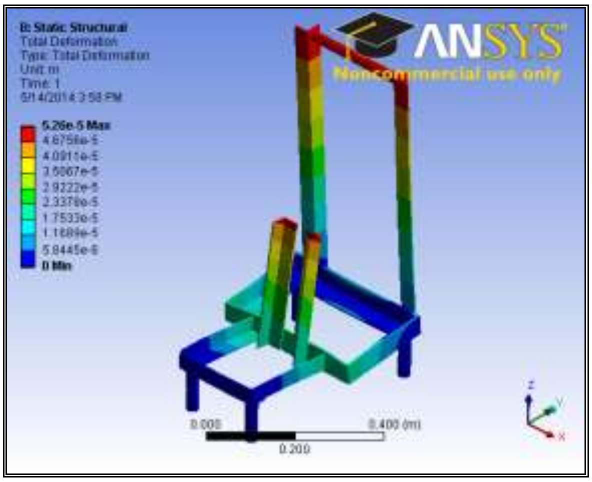


Fig. 5.5.1: Load distribution on trolley

The above figure 5.5.1 shows the constraints and load distribution which is due to the tank load acting on the main frame of the trolley and the pump load acts on the pillars provided to clamp the pump. The load of the tank which is 343.35 N is converted into pressure of 9480 Pa and applied to the main frame on which the tank sits. The load of the pump which is 34.335 N is divided into four equal parts and it is distributed on the four holes in the downward direction perpendicular to the hole axis. The table 5.5.1 shows the load distribution on Trolley;

Sr. No.	Boundary Condition	Value	Application area
A	Fixed Support	________	Legs
B	Pressure	9480 Pa	Base of Main Frame
C	Force	8.5838 N	Clamping Hole
D	Force	8.5838 N	Clamping Hole
E	Force	8.5838 N	Clamping Hole
F	Force	8.5838 N	Clamping Hole

Table 5.5.1: Load distribution on Trolley



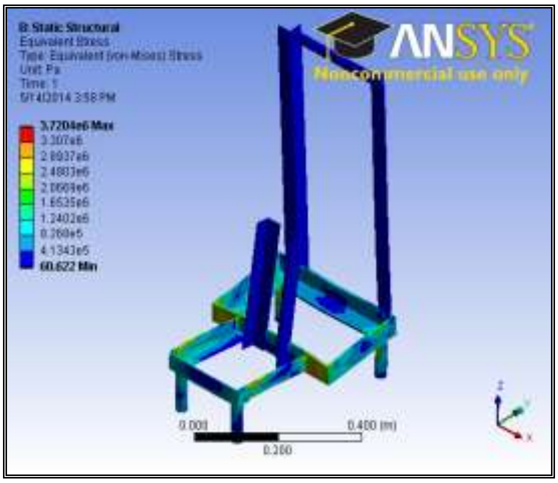


Fig. 5.5.2 Displacement Plot of trolley Fig. 5.5.3: Equivalent (Von-Mises) Stress Plot of Trolley.

Particulars	Value
Von-Mises Stress	3.7204 Mpa
Total Maximum Deformation	0.0526 mm

Table 5.5.2: von-Mises Stress and Deformation

The value of yield stress for mild steel is 250 Mpa. Hence Factor of Safety is given by:

$$Factor\ of\ Safety = \frac{Yield\ Stress}{Maximum\ Stress} = \frac{250}{3.72} = 67.204$$

The maximum deformation value is (Fig. 5.5.2) of around 0.0526 mm with loads exerted on the trolley which is acceptable level of deformation considering the dimensions of trolley. The maximum stress is 3.72 Mpa which is very less as compared to the yield strength of the material (250 Mpa) which gives the factor of safety as 67.204. Hence the Trolley is safe in working condition. The further optimization can be carried out with respect to weight distribution & dimensions. But we have not done it due to less availability of time.

VI. RISKS INVOLVED & SAFETY PRECAUTIONS

6.1 Risks Involved

The strong spray from a pressure washer can cause serious wounds that might first appear minor. Wounds that appear minor can cause a person to delay treatment, increasing risk for infection, disability or amputation. The fast, strong spray can throw objects that strike and injure others who are close by. Electric shock can occur if the pressure washer is not used properly and if safety instructions are not followed. Using small, gasoline powered engines to drive pump can cause carbon monoxide poisoning. Workers should not use any washers powered by gasoline engines inside buildings or other partially enclosed spaces unless the gasoline engine can be placed outdoors and away from air intakes [9].

6.2 Safety Precautions

- Never point a pressure washer at yourself or others [11].
- Never attempt to push or move objects with spray from the washer.
- Never use a gasoline powered washer in an enclosed space.
- If an extension cord must be used, keep the pressure washer's power cord connection out of any standing water, and use a heavy duty extension cord with components rated for use in wet locations.
- Keep both the power cord and extension cord connections as far away as possible from the item being washed and away from any water runoff.
- Wear rubber soled shoes that provide some insulation when using the pressure washer.
- Never cut or splice the pressure washer's power cord or extension cords.
- Always have a qualified electrician check the pressure washer for electrical problems after it has tripped a circuit breaker.
- Never allow children to operate a pressure washer. Keep children at a safe distance when using a pressure washer.
- **If you are hurt by a pressure washer:**

· Call 108 if emergency help is needed.
· Before treating the wound, wash your hands with soap and clean water.
· Remove any object that is in the way of caring for the wound.
· Put pressure on the wound with a clean cloth to stop bleeding.
· After bleeding has stopped, pour bottled or clean running water over the wound.
· Gently clean around the wound with soap and clean water.
· Pat dry and use an adhesive bandage or dry clean cloth to cover the wound.

VII. CONCLUSION & FUTURE WORK

7.1 Conclusion

The portable car wash is fabricated for its use in washing the vehicles of our institute. It can be concluded that the results were satisfied for the stable working of the machine and is as follows:

- The pressure developed by the machine is 100 bar and it is suitable enough to clean the vehicle by removing the grease and other dirt as can be seen during demo run.
- The model is working successfully and vehicle was washed satisfactorily during the demo run of the machine.
- The Pump runs continuously for 30 minutes. When the pump heats up it switches off automatically and it is allowed to be cooled for 15 minutes before it can be started again.
- The pump flow turns off when the trigger switch is released due to the presence of pressure switch inside the pump. This saves water and the pump need not be turned off by switching off the main switch while applying soap.
- From the analysis of trolley, the whole structure of the trolley is balanced and it can sustain the load from the tank and motor. Hence the trolley is safe to mount the pump-motor unit.

7.2 Future Work

As with most technologies there is endless advancements waiting to be discovered and the well established car wash is no different. From humble beginnings in the early 20th century the car wash as evolved beyond anyone's expectations. It has become almost amazing what technologies have been introduced to transform a simple car wash into the futuristic structures we see today. Here are the big technologies for the future:

- Steam Car wash

Steam washing is a new addition to how cars can be washed; using a steam jet it is safe on both the car exterior and interior. The majority of car washes will use 113 liters of water per car or 378 liters if washing at home. However a steam wash will only use around 4 liters of water (and doesn't give off waste water) per car making it cost and eco friendly.

- Self Serve Car Washes

Car washing has evolved from automatic tunnels to top of the range self serve facilities, especially in Australia. If you want a professional finish but want to wash your vehicle yourself there are a number of self service car washes with top of the range products and equipment. Many self serve car washes will have coin operated equipment and many in the future will have electronic pay facilities.

- Mobile Car Washing

In recent times many people have commitments that may restrict their spare time and activities such as car washing. There are many dedicated mobile car washing companies in Australia that will come to your home or office to wash or detail your car. This comes as convenience is a crucial part of living in the 21st century. Mobile car washing saves time driving to (and through) a car wash.

- Trolley Weight Optimization

The weight of the trolley can be optimized by a new design where in the holes can be drilled into the angles to reduce the weight and thereby making the trolley lighter.

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