Unmanned Firefighting Machine

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1.0 Problem Statement

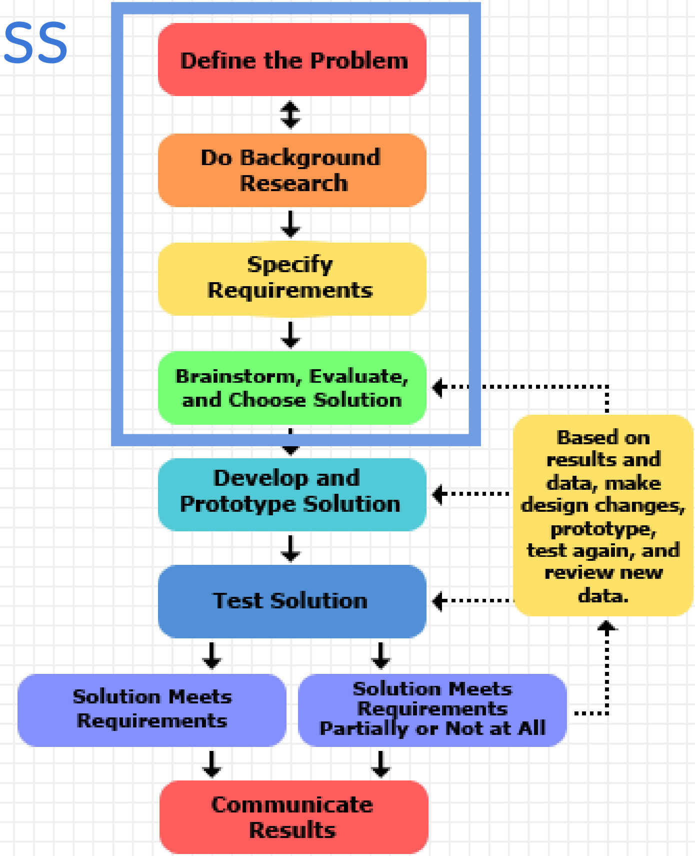
- To extinguish a fire, the fire fighters need to be very close to the fire area.
- very dangerous and caused safety issues for the person itself.
- For example, when a chemical factory is on fire, it may cause an explosion which will end up in sacrificing of fire fighter's life.
- The traditional method in extinguishing fire also not efficient and always take a long time in fighting fire.
- For our integrated design project, we decided to design a simple and low cost of Unmanned Ground Vehicle (UGV)

1.1 OBJECTIVE

- To design a low cost unmanned fire fighting machine which is able to extinguish fire at a long distance.
- To determine and illustrate how static failure theory can be applied to identify the factor of safety of the machine.
- To obtain the suitable projectile of water spray from the nozzle and the relevant speed of Unmanned Ground Vehicle.
- To improve the understanding on mechanical engineering design, mechanical engineering analysis and CAD drawing.
- Your audience will listen to you or read the content, but won't do both.

2.0 Methodology

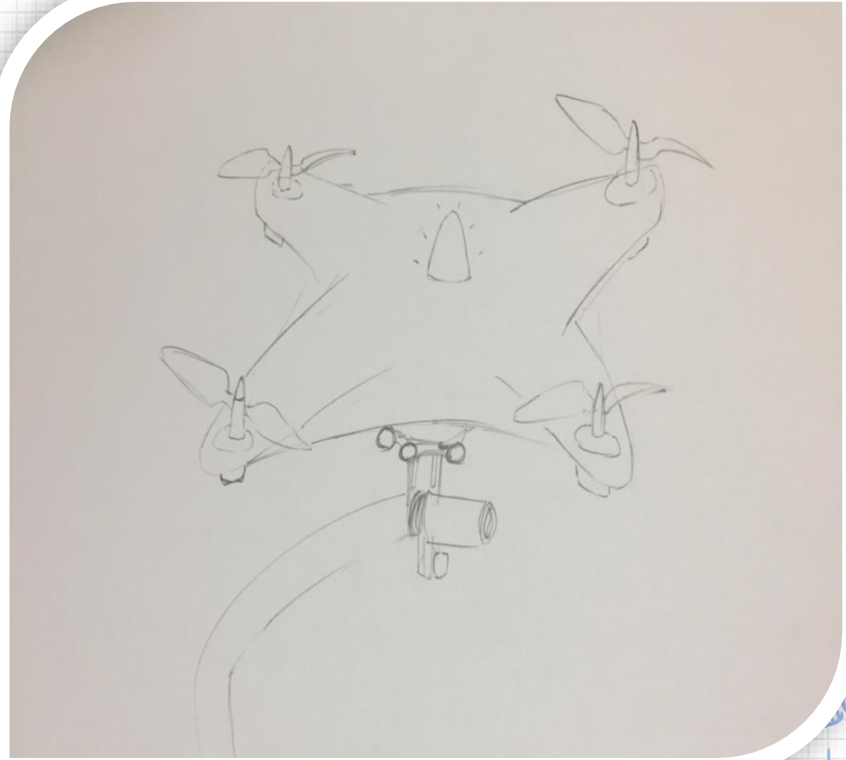
2.1 DESIGN PROCESS



2.2 DESIGN IDEA AND SKETCHING

IDEA 1 : UNMANNED AERIAL VEHICLE

- An aircraft without a human pilot abroad and a firefighting drone
- Can overcome the limits of traditional firefighting.
- Technologies such as gas sensors and improved cameras are added to commercial drones to aid fire fighters.
- Hoses attached to the drones can supply water to extinguish the fire in high places.

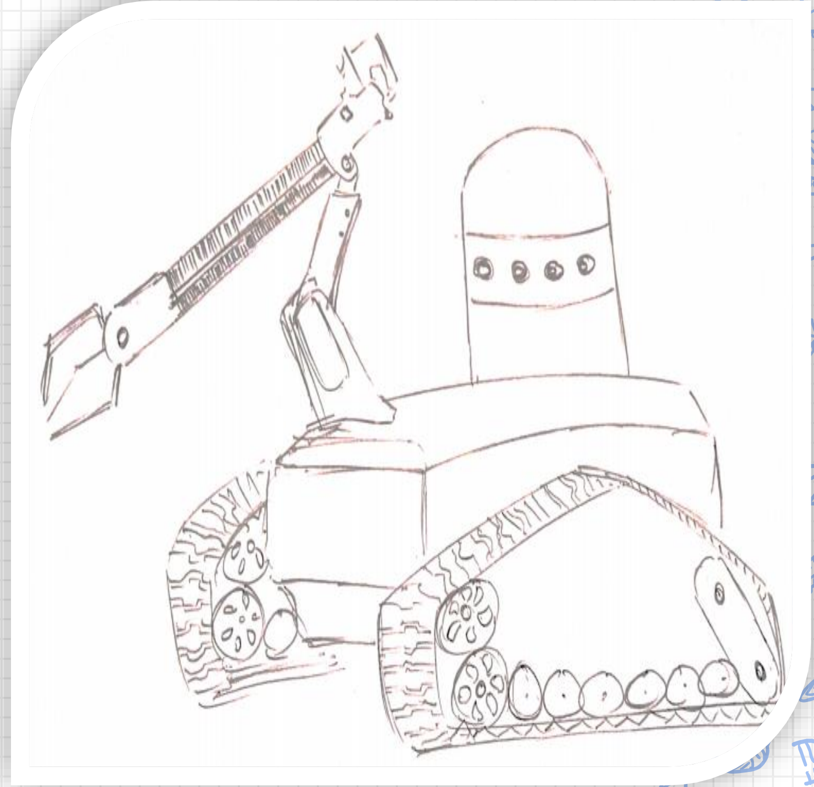


IDEA 2 : SEARCH AND RESCUE ROBOT

* Controller is used to remote the robot and conveyer belt is used to enable it to travel on uneven terrain.

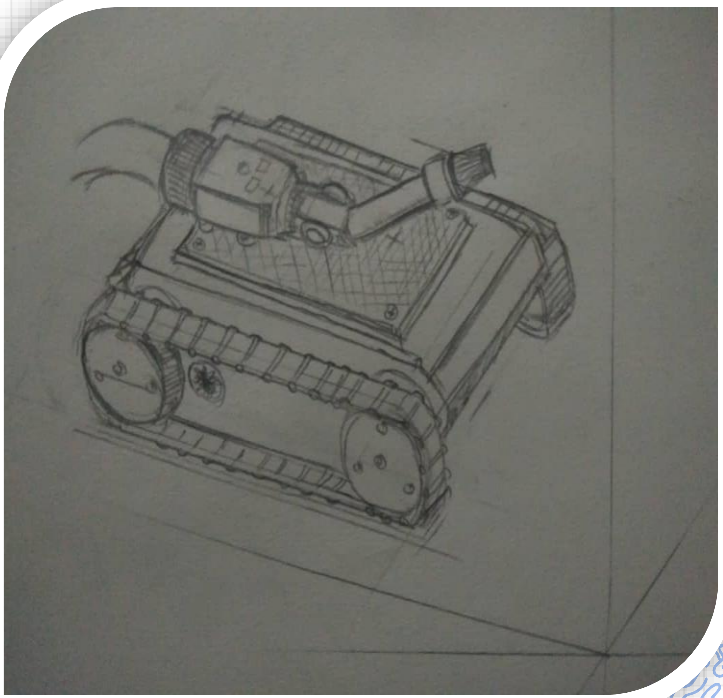
* Infrared camera is used to detect trapped people. Robotic arm can be used to remove the rubbles

* 360 degrees carbon dioxide sprayer is used to extinguish fire.



IDEA 3 : UNMANNED GROUND VEHICLE

- Controlled by a man far from burning site.
- A high velocity fan is installed to ventilate the smoke-logged areas quickly and effectively.
- A high output of water mist, the water jet or foam can extinguish the fire in high places.



Unmanned Aerial Vehicle

Strength	Weakness
High speed. It takes a very short time for preparation and can immediately extinguish fire just after the arrival of fire fighter.	Unable to be in air for long. It is highly energy consuming and so cannot be used for a long period.
High reach ability. It can reach high place and extinguish fire which is barely possible to be reached by ground vehicle.	Unable to extinguish a large amount of fire at one time. Only limited amount of water can be carried.

Search and Rescue Robot

Strength	Weakness
Wider and clearer vision as infrared camera is installed.	Low mobility. Any narrow place will restrict the movement of this machine.
Reduce the safety risk. This machine can go much deeper into the burning site as compared to the other two.	The carbon dioxide sprayer can only carry a limited amount of carbon dioxide.

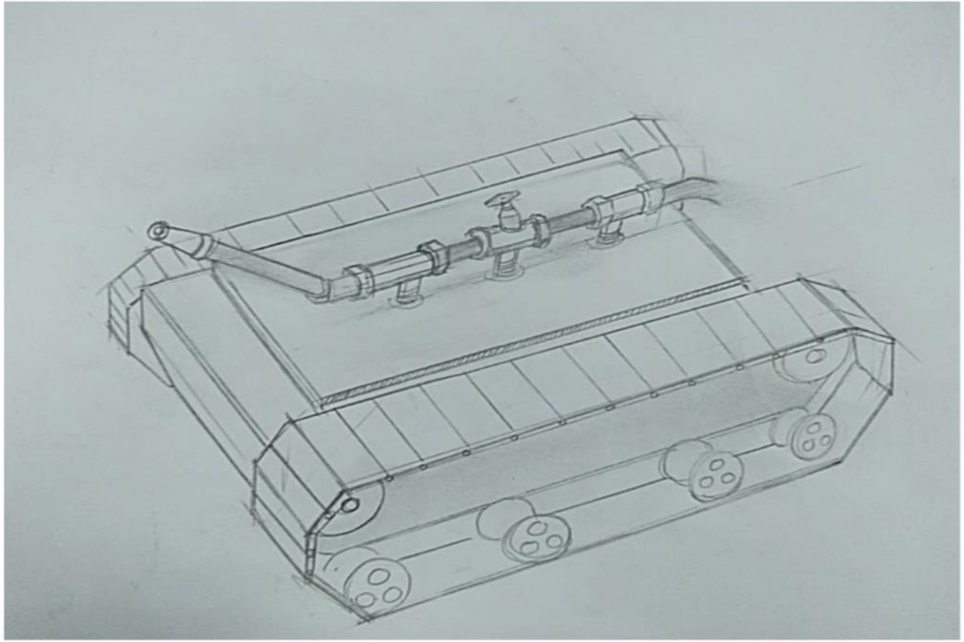
Unmanned ground vehicle

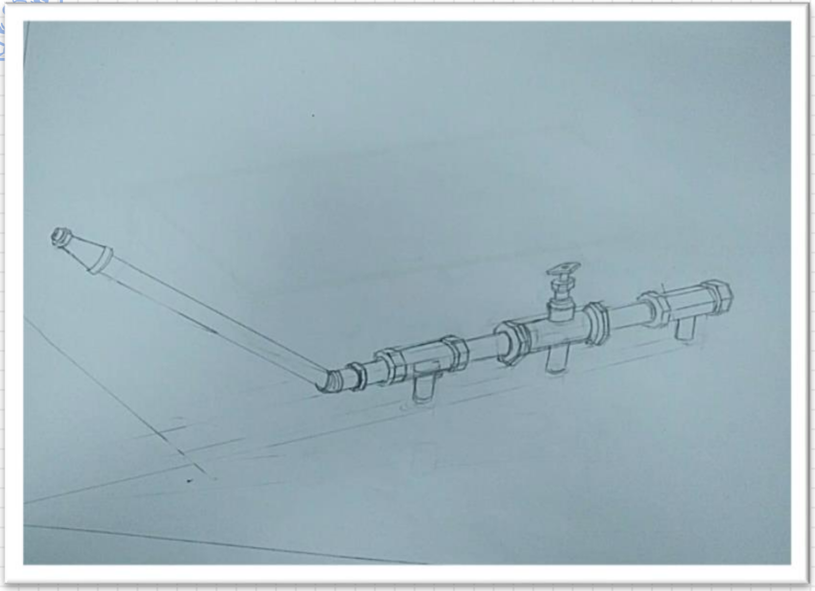
Strength	Weakness
High flow rate and unlimited source of water. It can tackle large amount of industrial fire.	High cost for material and technology.
Clearer vision as high velocity fans can be used to ventilate smoke.	Duration for fabrication is longer as the machine is bigger in size and is more complicated.

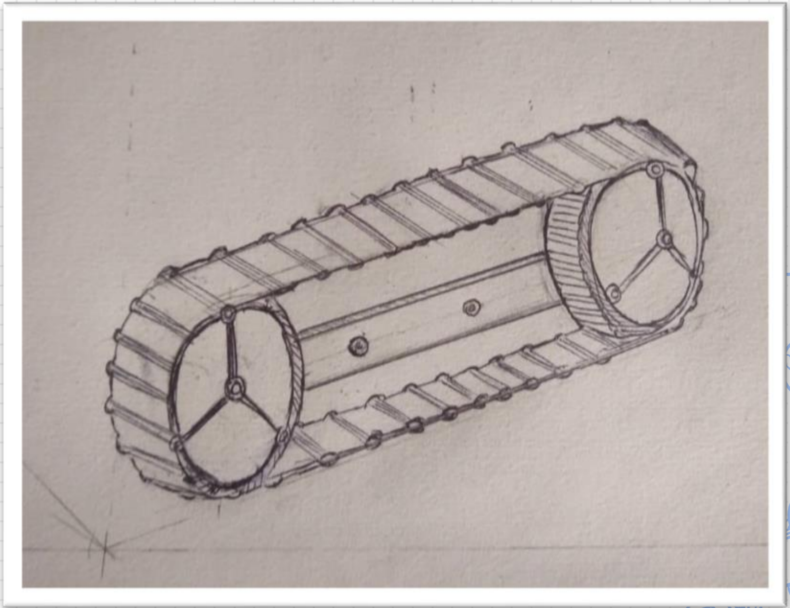
∴ After debating on the pros and cons, the unmanned ground vehicle is chosen as the final design.

- Due to the ability of the machine to cope with severe fire and the convenience in reaching the source of water,

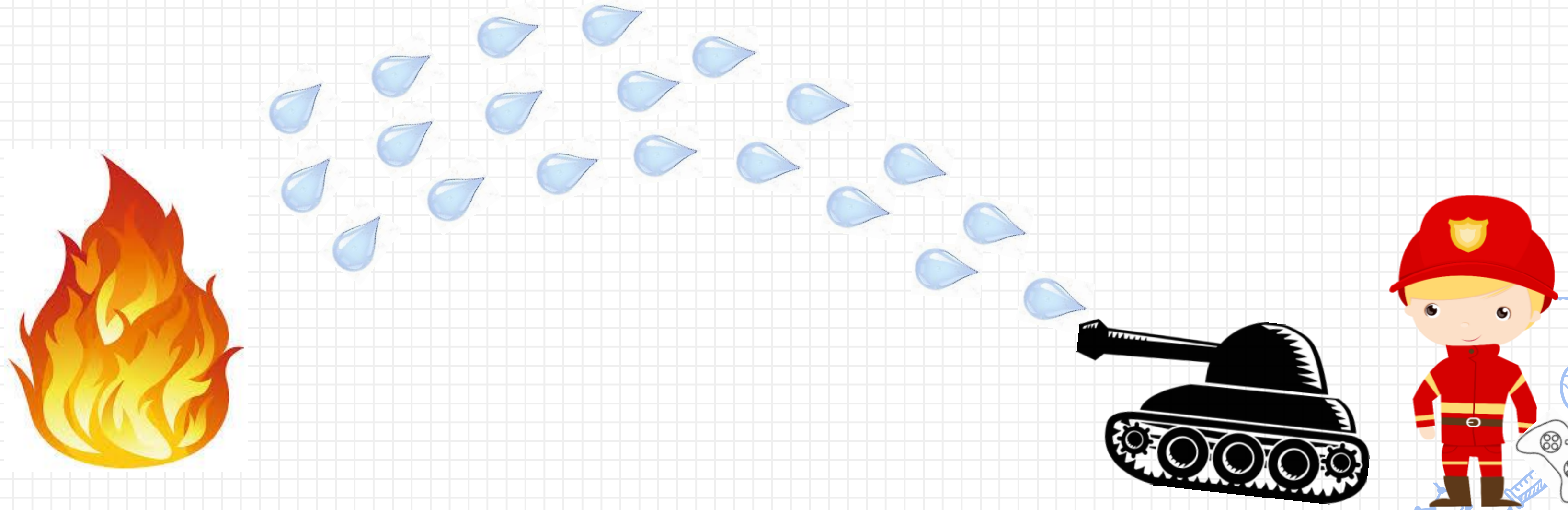
The sketching of final design





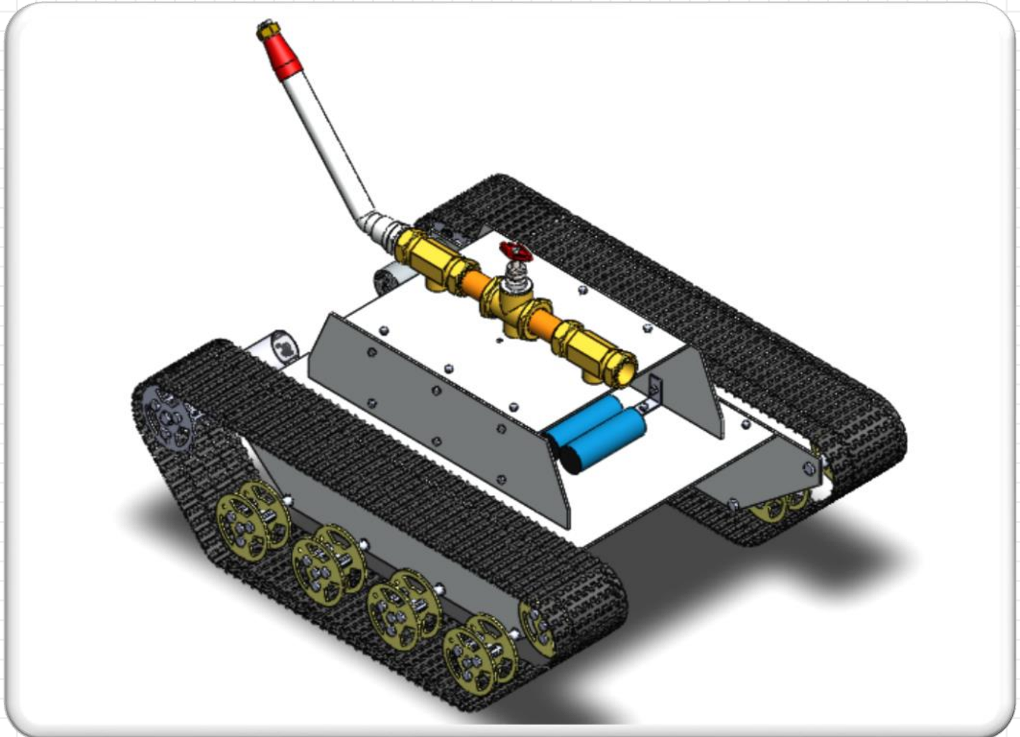


2.4 MACHINE WORKING ANIMATION



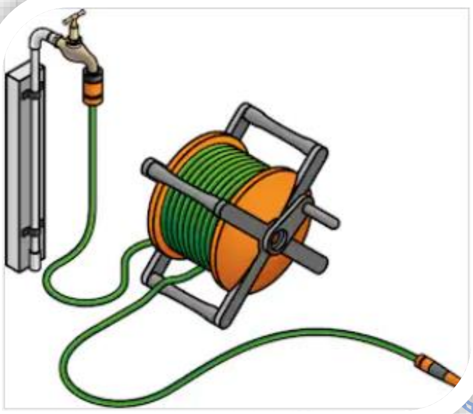
3.0 Final Design With Drawing

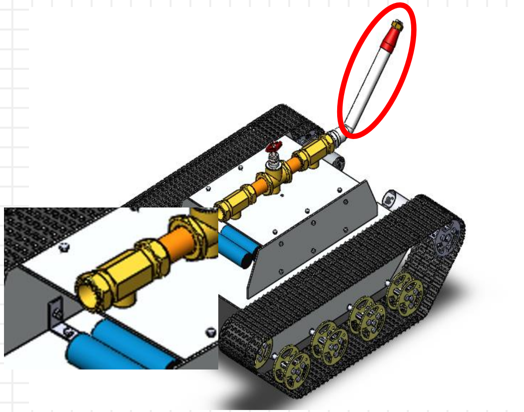
FINAL DESIGN:



3.1 WORKING PRINCIPLE

- With our design. the water hose will be connected to the main water source from outdoor taps





- This hose is then connected to the body of the unmanned ground vehicle via valves. This valve then connects it to the water nozzle which in turn will shoot water out, extinguishing the fire.

3.2 MATERIAL SELECTION

BODY:

Material	Advantage	Disadvantage
Aluminium	• lighter metal in terms of density • more cheaper	• it's more prone to breaking out right • It also doesn't absorb vibrations well
Steel	• known for being tough and hard • heat resistance	• Quite expensive • heavy
Copper	• Conductivity and heat resistant • Cheap	• High ductility and malleability • Cant withstand high force

VERDICT:

Steel is chosen due to its ability to withstand:

- HIGH PRESSURE
- HIGH HEAT

NOZZLE AND CONNECTING PARTS

Component	Material	Advantage	Disadvantage
T-shaped tube	PVC	• Low cost • Rust resistance • Due to less friction it saves the energy in the conveyance of water.	• Can't stand with high temperature • Due to their non-decomposing property
Automated close valve			
Normal tube			
2 different size tube left and right			

VERDICT: PVC IS CHOSEN BECAUSE:

- ABLE TO WITHSTAND HIGH PRESSURE FROM WATER
- LOW COST

TRACK AND WHEEL

Material	Material	Advantage	Disadvantage
Bearing wheel	aluminium	• High strength • Economical	• Quite expensive • Energy intensive to produce
Driving wheel			
Track	Plastic	• Low cost • Rust resistance • Smooth moving on land	• Can’t stand high temperature • Due to their non-decomposing property

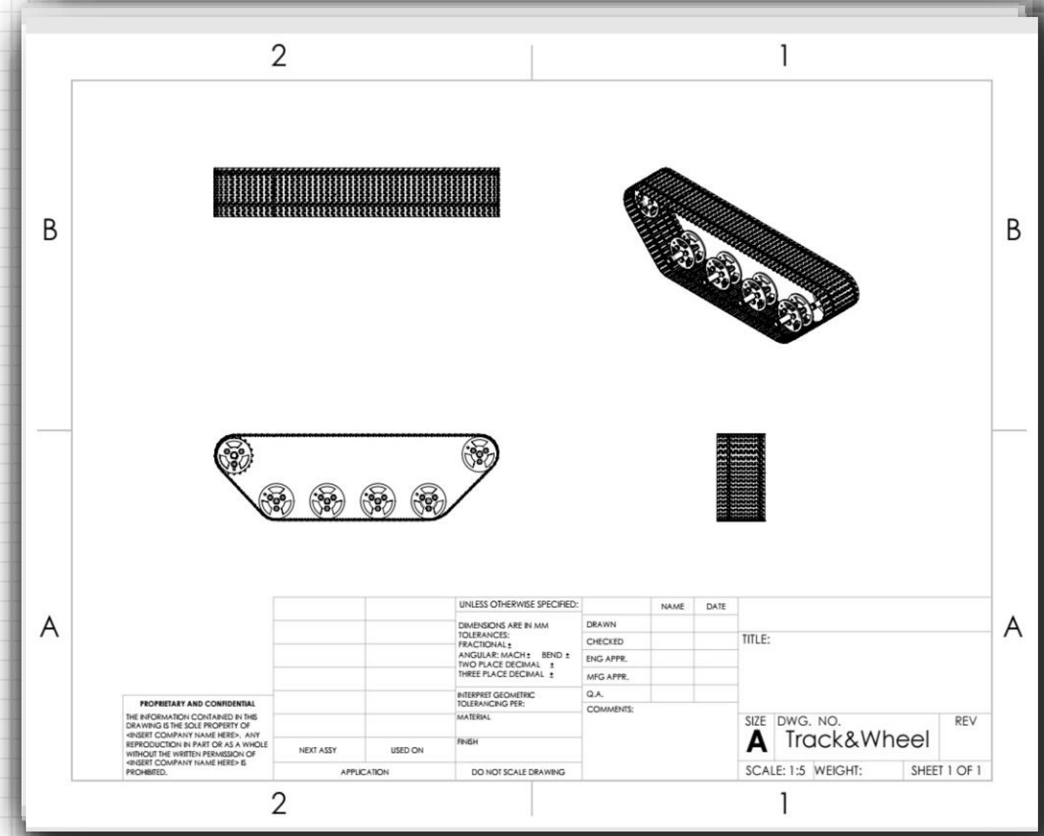
METAL FASTENERS:

i. BOLTS
ii. RIVETS
iii. NUTS
iv. SCREWS
v. BRACKETS

Advantage	Disadvantage
Temperature resistance	Slightly more expensive
Resistance of corrosion	Need to be properly fastened
Durability & longevity	Steel cannot be mold in any direction
Low maintenance & high value	Steel is heavy

VERDICT: SUITABLE MATERIAL CHOSEN IS STEEL.

ORTHOGRAPHIC DRAWINGS OF PARTS



4.0 Engineering Analysis

Based on the model we designed, several calculations are made as such:

1. FLOW RATE
2. PROJECTILE
3. WHEEL VELOCITY
4. BOLT & FREE BODY DIAGRAM

FLOW RATE CALCULATION

h = 0.18m from ground to the entrance of pump

By using Bernoulli Equation,

$$\frac{P_1}{\rho}+\frac{v_1{}^2}{2} + gh = \frac{P_2}{\rho} + \frac{v_2{}^2}{2} + gh$$

$$\frac{126-101kPa}{997} + \frac{1^2}{2} = \frac{v_2{}^2}{2} + (9.81)\ (0.18)$$

v_2 =6.90 m/s

Find flow rate, Q,

A_1 = 0.015 m

A_2 = 0.010 m

$v_2 = V_1$ = 6.90 m/s

$\therefore$ Q = AV

$A_1V_1 = A_2V_2$

0.015 (6.90) = 0.010 V_2

V_2 = 10.35 m/s

PROJECTILE CALCULATION

Maximum horizontal distance:

$$= \frac{y^2 \sin(2\theta)}{g}$$

$$= \frac{(10.35)^2 \sin(2 \cdot 45)}{9.81}$$

$$= \mathbf{10.92m}$$

Vertical distance:

$$= \frac{y^2 \sin^2(\theta)}{2g}$$

$$= \frac{(10.35)^2 \sin^2(45°)}{2(9.81)}$$

$$= \mathbf{2.73m}$$

∴ Maximum vertical distance:

$$= 2.73 + 0.29\ (m) = \mathbf{3.02m}$$

WHEEL VELOCTY CALCULATION

Gear ratio, n

Diameter motor gear = 3cm

Diameter wheel gear = 5cm

n = 5/3

Motor gear angular velocity, ωm:

$$\omega m = \frac{125\ \text{rpm}}{60\ \text{s}} \times 2\pi$$

= **13.08 rad/s**

Wheel gear angular velocity, ωw:

$$\omega w = 13.08\ \text{rad/s} \times \frac{3}{5}$$

= **7.848 rad/s**

Linear velocity of wheel, vw :

vw = 0.025 x 7.848 rad/s

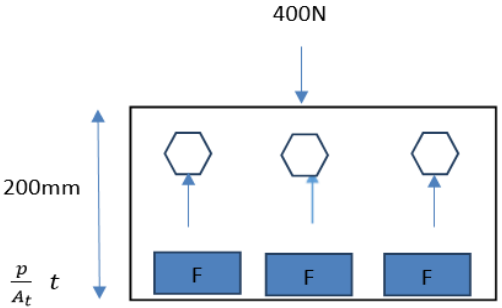
vw = rωw

= **0.1982 m/s**

BOLT CALCULATION & FREE-BODY DIAGRAM

Force acting on Board

$P = \frac{W}{3} = \frac{40}{3} = 13.33\ N$

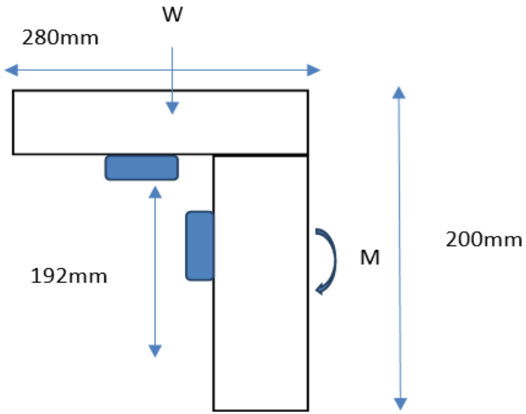


Shear of Bolt $A_t = 8.78mm^2$ $t = \frac{p}{A_t}$ t

$$= \frac{13.33}{5.78 \times 10^{-6}} = 2.27\ Mpa$$

Bending Tensile u

$= \frac{Fl}{nl^2} = \frac{(40)(0.2)}{3(0.051)^2} u = 1025.25\ Mpa$



$F_{max} = ul_{max}$

$= (1025.25)(0.0051)$

$= 5.23\ N$

CONTINUATION,

$$\sigma = \frac{F_{max}}{A_t}$$

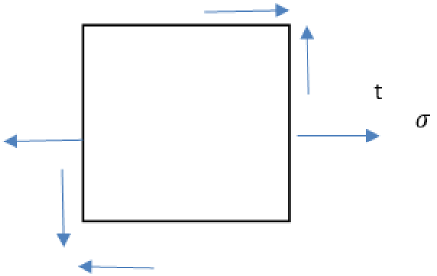
$$= \frac{5.23\ N}{(8.78 \times 10^{-6})} = 6.00\ Mpa$$

$$\sigma_{1,2} = \frac{\sigma}{2} \pm \sqrt{(\frac{\sigma}{2})^2 + t^2}$$

$$= \frac{6.00}{2} \pm \sqrt{(\frac{6.00}{2})^2 + (2.27)^2}$$

$$= 3.00 \ \pm 3.76\sigma_1$$

$$= 6.76 Mpa \sigma_2 = -0.76\ Mpa$$



Tresca

$$\sigma_1 - \sigma_2 = \sigma_{allow} \sigma_{allow} = 7.52\ Mpa$$

Von Misses

$$\sigma_{1^2} - \sigma_1 \sigma_2 + \sigma_{2^2} = \sigma_{allow^2} \sigma_{allow}$$

$$= \sqrt{(6.76)^2 - (6.76)(-0.76) + (-0.76)^2}$$

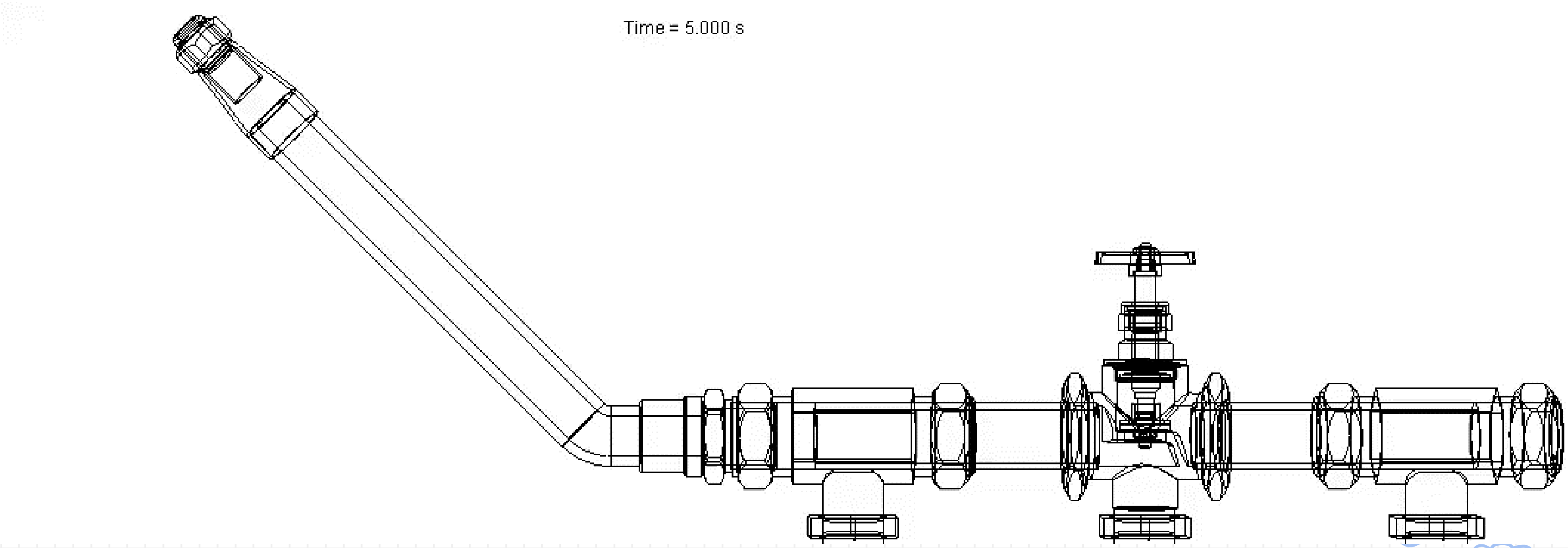
$$= 7.17\ Mpa$$

FACTOR OF SAFETY

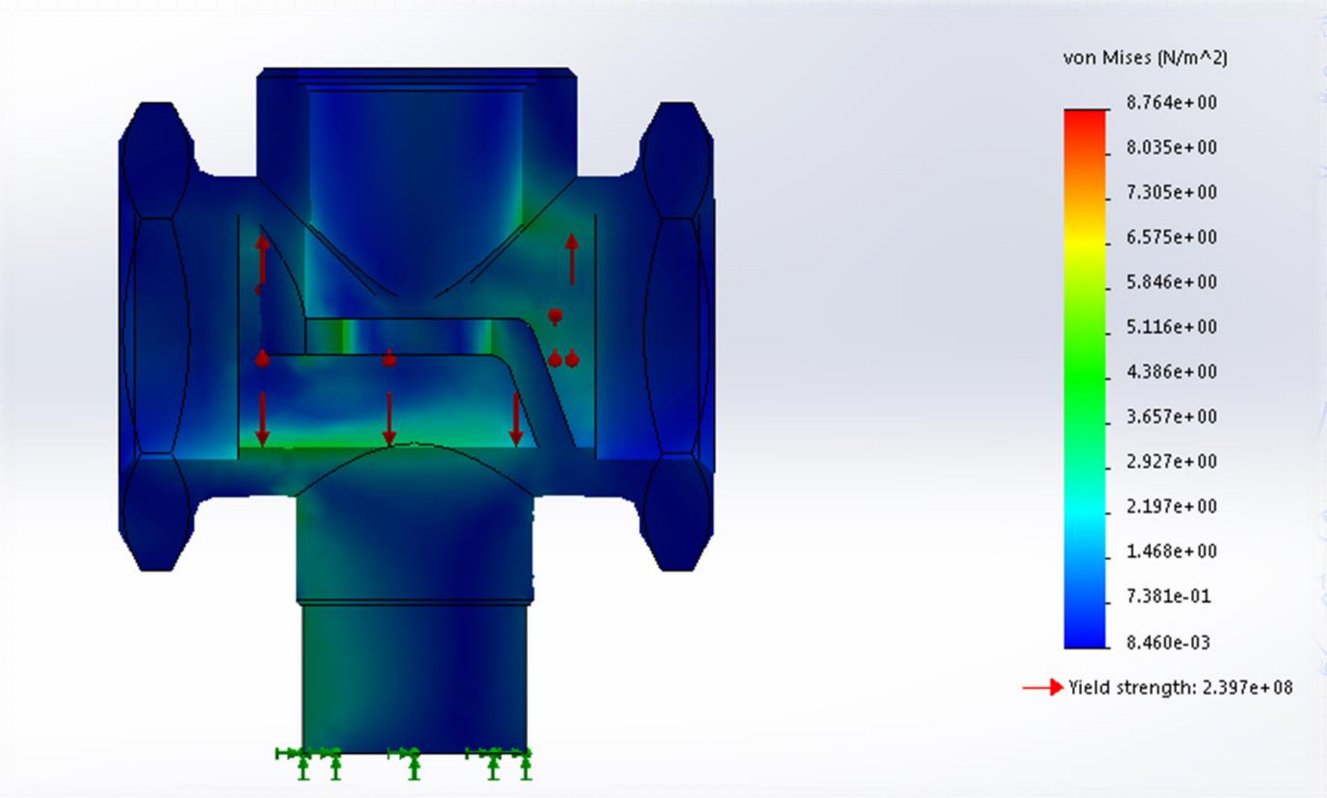
Failure Mode and Theory	Factor of Safety
Shear Stress	$n = \frac{S_p}{t} = \frac{650}{2.27} = 286.34$
Bending Tensile	$n = \frac{S_p}{\sigma} = \frac{650}{6.00} = 108.3$
Tresca Theory	$n = \frac{S_p}{\sigma_{allow}} = \frac{650}{7.52} = 86.43$
Von Misses Theory	$n = \frac{S_p}{\sigma_{allow}} = \frac{650}{7.17} = 90.65$

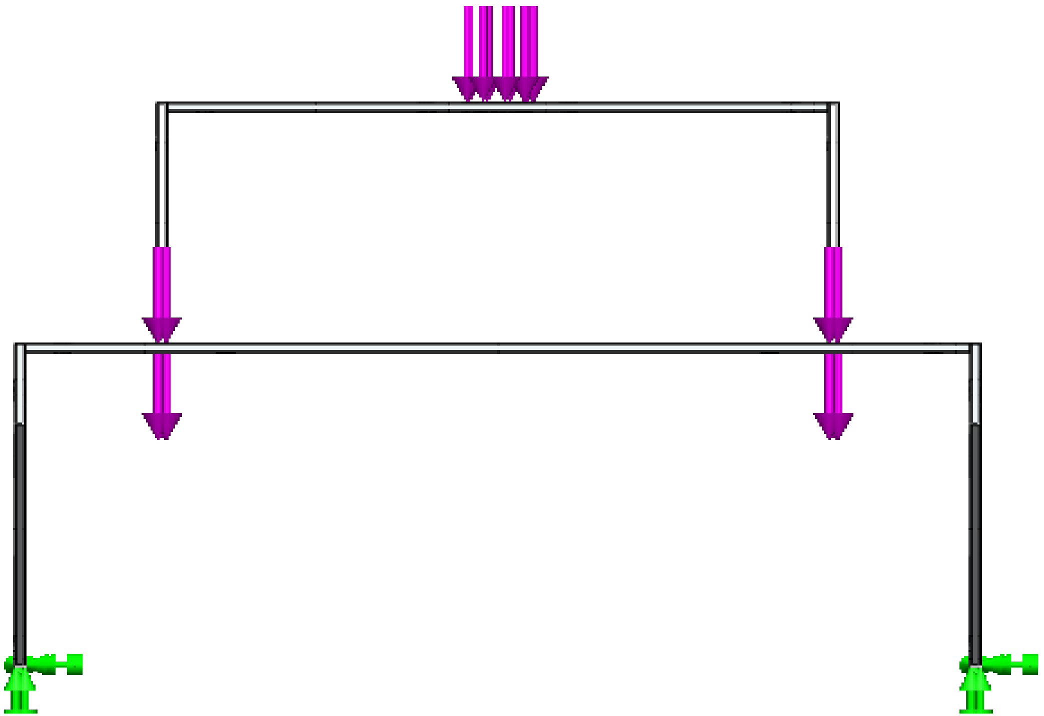
5.0 Visual Aids

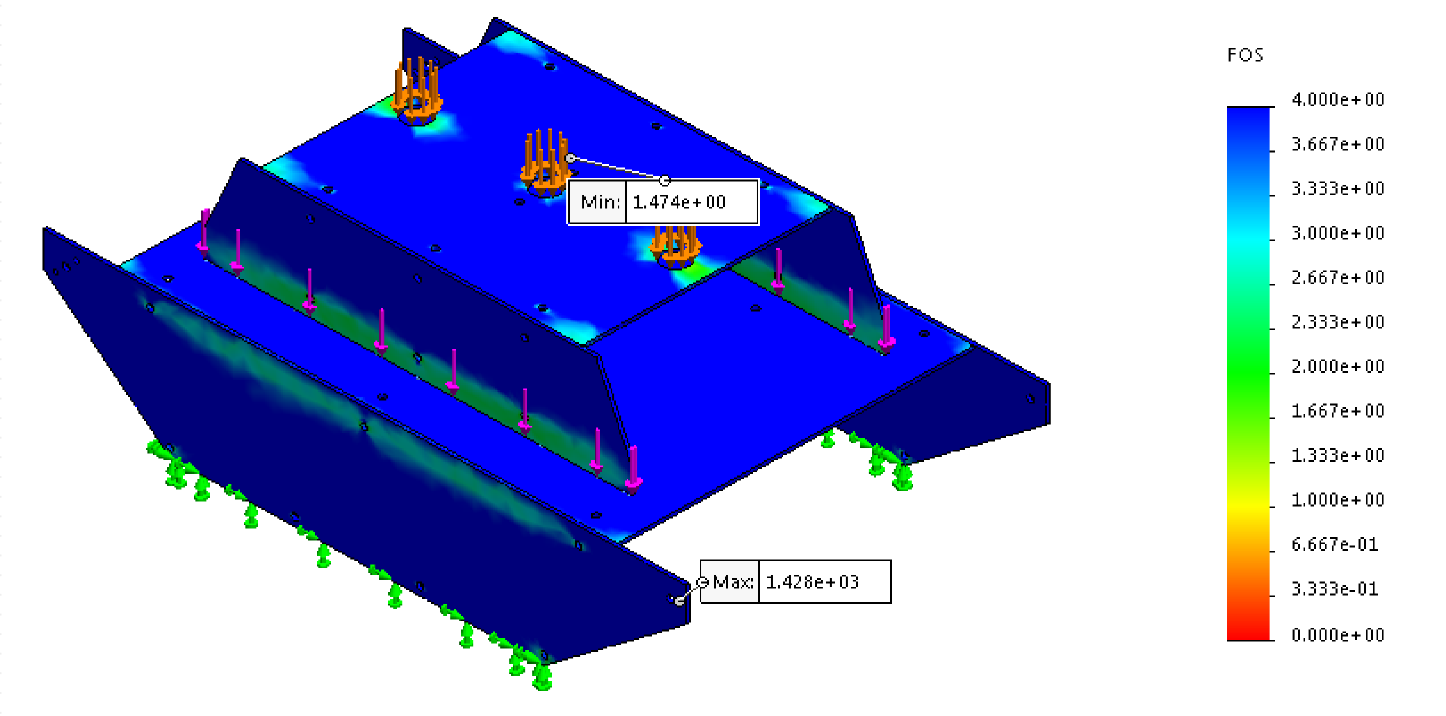
5.1 NOZZLE WATER SIMULATION



5.2 SIMULATION






Min: 1.474e+00
Max: 1.428e+03
FOS
4.000e+00
3.667e+00
3.333e+00
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2.000e+00
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1.000e+00
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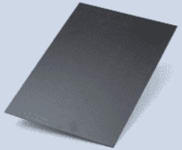
6.0 Cost

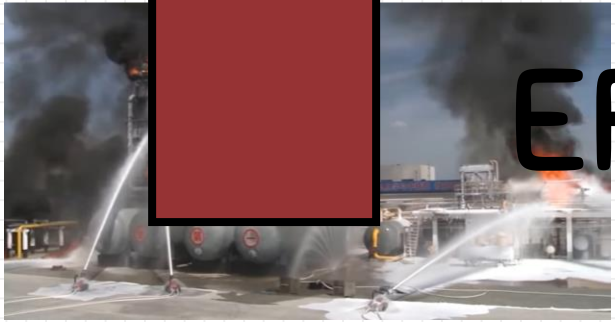
	Material	Quantity	Price(RM)
1	Stainless steel plate(2*150*150)mm 	2	55.00
2	Motor DC 12V 125 rpm 	1	42.00
3	Automatic valve 	1	12.20

4	Infrared tracking sensor 	1	3.60
5	Controller	1	40.00
6	T shaped tube 	1	7.45
7	High pressure tube 	5metre	38.00

8	PU Tube 	5metre	7.00
9	Track wheel	A pair	57.00
10	Arduino Set 	1 set	46.00
	TOTAL		**308.25**

CONCLUSION

SAFETY



EFFICIENCY

THANK YOU!