EXPERIMENTAL ANALYSIS OF UREA BED METHOD FOR NEUTRALIZATION OF TOXIC ROCKET PROPELLANTS IN ROCKET ENGINE TEST FACILITIES

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Abstract- The project aims to develop a urea bed neutralization method for neutralizing toxic rocket propellants in rocket engine test facilities. Dinitrogen tetraoxide and Monomethyl hydrazine are the hypergolic propellants used in rocket propulsion. These propellants are very toxic and high pollutant to the atmosphere. Rocket engines are to ground tested mandatory for performance evaluation. In rocket engines, test facility propellants are stored in the propellant tank with high pressure. After engine testing, propellant has to be vented for safe test stand condition. But these propellant fumes polluting the environment. So neutralization of this fume of propellants is very essential for a clean and safe environment. Hence a suitable neutralization method has to be developed with suitable agents and the output has to be analysed.

Keywords- *Ceramic balls. Monomethyl hydrazine, Neutralization, Nitrogen tetraoxide & Urea bed.*

I.INTRODUCTION

A rocket engine uses stored rocket propellants as the reaction mass for forming a high-speed propulsive jet of fluid, usually high-temperature gas. Rocket engines are reaction engines, producing thrust by ejecting mass rearward, by Newton's third law. Most rocket engines use the combustion of reactive chemicals to supply the necessary energy. Launch Vehicles propelled by rocket engines are commonly called rockets. Rocket vehicles carry their oxidizer, unlike most combustion engines, so rocket engines can be used in a vacuum to propel spacecraft and ballistic missiles. Chemical rockets are powered by exothermic reduction-oxidation chemical reactions of the propellant. A rocket engine test facility is a location where rocket engines may be tested on the ground, under controlled conditions. A ground test program is generally required before the engine is certified for flight. Ground testing is very inexpensive in comparison to the cost of risking an entire mission or the lives of a flight crew. The advantage of altitude testing is to obtain a better simulation of the rocket's operating environment. Air pressure decreases with increasing altitude. Effects of the lower air pressure include higher rocket thrust and lower heat transfer. Liquid-propellant rockets use one or more propellants in a liquid state fed from tanks. Rocket propellant is mass that is stored, usually in some form of the propellant tank, or within the combustion chamber itself, before being ejected from a rocket engine in the form of a fluid jet to produce thrust. Most chemical propellants release energy through redox chemistry, more specifically combustion. As such, both an oxidizing agent and a reducing agent (fuel) must be present in the mixture. Decomposition, such as that of highly unstable peroxide bonds in monopropellant rockets, can also be the source of energy. The main difficulties with liquid propellants are also with the oxidizers. Storable oxidizers, such as nitric acid and nitrogen tetroxide, tend to be extremely toxic and highly reactive, while cryogenic propellants by definition must be stored at low temperature and can also have reactivity/toxicity issues. If the products of combustion from the rocket firing include flammable or explosive materials, the chamber must be inerted, typically with gaseous nitrogen (GN2). The inerting process prevents a build-up of potentially explosive materials inside the chamber or exhaust ducting.

2. PROBLEM DEFINITION

Rocket engines are to ground tested mandatory for performance evaluation. In rocket engines, test facility propellants are stored in the propellant tank with high pressure. After engine testing, propellant has to be vented for safe test stand condition. But these propellant fumes polluting the environment. The slow and long venting process is the present method used for reducing pollution.

3. PROPOSED METHOD

A separate neutralizer tank has to be established with urea solution and ceramic balls as absorbent. The propellant vent will be passed through this solution and it has been neutralized. Neutralized vapour will be analysed with a pollution monitor system.

4. ENGINEERING DESIGN

Concentration of NOx =756 mg/m^3 =0.00076 kg/sec
Empirical multiplier value = 6
Height Transfer unit = 9.5 standardised
M-fraction of NOx at equilibrium with the liquid = 6
Environmental Management Agency (EMA) regulatory standard imposed on the level of flue gas cleanliness at 95 % efficiency
NO_2 flow volume ate = 67.277 m^3/sec
Since the EMA regulatory standard imposes a 95% NO_2 removal efficiency, then

$$\eta = 1 - Y_o / Y_i$$

Where 1 mole of flue gas = 0.0288 kg/sec of NO2 = 0.000756 kg/sec of NO_2.

$$\frac{0.000756 \times 1}{0.0288} = 0.2778 \text{ kg / s}$$

Therefore Y_{in} =0.2778kg/s

Calculating Y_{out}

η= 1 – Yout/Yin

0.95 = 1-Yout/0.02625

Y_{out}=0.0031

For the η to be 95% NO_2 removal to be attained, the mass flow rate of the flue gas flowing should be converted as flows:

1000ft^3/m^3=283.3m^3/min

=308.7kg/min

m◦=5.145kg/sec

Calculating the minimum amount of slurry required

$CaCo_3 + 2H_2O + 1/2NO_2 \rightarrow Ca(NO_4.)2H_2O + CO_2$

2kg $CaCo_3$ = 1kg NO_2

= 0.00075× ½ =0.00378kg/$m^3$$CaCo_3$

$$L_{min} = \frac{m}{1+c}\left(1 - \frac{Yout}{Yin}\right)$$

= 4.8 m^3/sec

β=mV (1+c)L

Where M is the fraction of NO_2 in equilibrium with the liquid slurry. Vis the mass flow rate of flue gas

β is the parameter determination value (0.05≤β≤1.0).

$$\beta - \frac{36 \times 5.15}{(1+6) \times 328.7}$$

$$= 0.08$$

Calculating the height the tower

$$H = N \times HTU$$

$$N = \frac{\ln((1-\eta\beta)) \div (1-\eta)}{(1-\beta)}$$

$$\frac{\ln((1-0.95 \times 0.08) \div (1-0.95))}{(1-0.08)}$$

= 2.01

= 2.01×5ft

= 10.1ft

= 3.2m

Therefore the height of the tank is 3.2 m

Calculating the radius and area of the tank

Q	=	AV
67.277	=	A×5.145
67.277	=	π×r2×5.145
r^2	=	3.1623m^2

Therefore radius = 1.5m

Area of the neutralization tank =3.20m^2

Calculating the volume flow rate of absorbent from the tank.

Q = Capacity of tank/time taken to empty the tank

= 390/3600 = 0.05 m^3/sec

5. EXPERIMENTAL SETUP

The neutralization tank vessel is stainless steel. having the characteristics such as high strength, corrosion resistance, durability and also high processability. In packed neutralization tank, urea solution is poured over packing material contained between support trays. A urea solution film coats the packing through which the exhaust gas stream is forced. Pollutants are collected as they pass through the packing, contacting the liquid film. Therefore, both gas and liquid phases provide energy for the gas-liquid contact. A wet-film scrubber uses packing to provide a large contact area between the gas and liquid phases, turbulent mixing of the phases, and sufficient residence time for the exhaust gas to contact the liquid.

These conditions are ideal for gas absorption. Large contact area and good mixing are also good for particle collection; however, once collected, the particles tend to accumulate and plug the packing bed. The exhaust gas is forced to make many changes in direction as it winds through the openings of the packed material. Large particles unable to follow the streamlines hit the packing and are collected in the liquid. As this liquid drains through the packing bed, the collected particles may accumulate, thus plugging the void spaces in the packed bed.

For gas absorption, packed scrubbers are the most commonly used devices. The wet film covering the packing enhances gas absorption several ways by providing large surface area for gas-liquid contact, turbulent contact (good mixing) between the two phases such as long residence time and repetitive contact. Because of these above features, urea bed neutralizer tank are capable of achieving high removal efficiencies for many different gaseous pollutants. Urea bed neutralizer tank are typically designated by the flow arrangement used for gas-liquid contact or by the material used as packing for the bed. The exhaust stream being treated enters the bottom of the tank and flows upward over the packing material. Liquid is introduced at the top of the packing by sprays and it flows down over the packing material. As the exhaust stream moves up through the packing, it is forced to make many winding changes in direction, resulting in intimate mixing of both exhaust gas and liquid streams. This counter current-flow arrangement results in the highest theoretically achievable efficiency. The most dilute gas is contacted with the purest absorbing liquor, providing a maximized concentration difference (driving force) for the entire length of the tank. Packaging materials are the heart of a packed low cost wet packed bed scrubber since they provide a surface over which the scrubbing liquid flows, thereby creating a large surface area for mass transfer between the gas and the scrubbing liquid. They are high density ceramic balls which is usually 2.5cm in size. ceramic balls packing's are systematically stacked on top of each other so as to lower pressure drop and also the stack packaging provides better liquid distribution over the entire surface of the packaging. Gas ducting from the rocket engine test facility to scrubber inlet, The inlet ducting from the propellant tank to the scrubber is usually made of mild steel which is highly cost effective in a hot and dry gas application. With the use mild steel, this will limit chances of slurry carryover of liquid because acid will form. Flue gas enters at 35^0C through the inlet pipelines.

6. WORKING PRINCIPLE

Urea bed neutralization system wet scrubber involves mass transfer operation. Mass transfer of the urea packed bed neutralization method is defined as the transfer of gas molecules to the liquid. The operation of mass transfer occurs between a soluble gas and a liquid solvent where the gaseous pollutant is transferred from the process stream (gas phase) to the scrubbing liquid (liquid phase).The mass transfer rate is important for the performance of the packed bed scrubbers because it greatly influences the rate at which the pollutant is removed. Absorption, an operation of mass transfer is the mechanism used in packed bed scrubber to remove gaseous contaminant from the exhaust gas stream. Absorption is said to occur when the gaseous pollutants dissolve in the scrubbing liquid droplets. The driving force for absorption is the concentration difference of the contaminants between the gas and liquid phases. Absorption will cease if the concentration of contaminants in the gas phase are in equilibrium with the pollutant's concentration in the liquid phase. Solubility of pollutant in the liquid is a factor controlling the concentration difference. A gas which is more soluble ends to be absorbed faster. Absorption is classified into physical absorption and chemical absorption. Physical absorption occurs when the absorbed gas is simply dissolved into the liquid solvent. When there is a reaction between the absorbed gas and the liquid solvent, it is a chemical absorption. Chemical absorption provides efficient scrubbing for insoluble gases such as chlorine and sulphur dioxide. There are two primary working mechanisms associated with particle removal from the process stream in packed bed scrubber, namely impaction and Brownian diffusion. Impaction results when dust particles cannot follow the curving streamlines around a scrubbing liquid droplet. The particle continues to move towards the droplet along a less curvature path due to inertia and finally it separates from the streamlines and hit the liquid droplet. The rate of impaction depends on the diameter of the particle and the relative velocity between the liquid droplet and the particle. Impaction is usually significant with larger particle and with increased velocity. A particle size that is more than 1µm is generally collected by impaction. The rate of diffusion is dependent on the size of liquid droplet, particle diameter and the relative velocity between the particle and the liquid droplet. Diffusion increases with decreased particle size and liquid droplet size. It decreases with increased relative velocity. This mechanism is able to remove particle which is less than 0.1 µm .

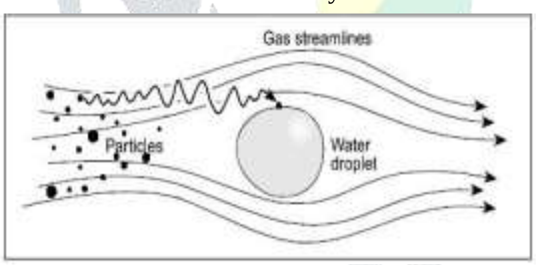

Fig 1. Mechanism of diffusion

For both impaction and diffusion, collection efficiency increases with an increase in relative velocity (liquid- or gas-pressure input) and a decrease in liquid-droplet size. However, collection by diffusion increases as particle size decreases. This mechanism enables certain scrubbers to effectively remove the very tiny particles (less than 0.1µm). In the particle size range of approximately 0.1to1.0µm, neither of these two collection mechanisms (impaction or diffusion) dominates.

7. RESULTS AND DISCUSSION

Following the trend of the results obtained, that there is a linear inverse relationship between distance and the value across the pollution level monitor sensor. The following results were obtained from the experiment near the output of the neutralization tank.

S.NO	Distance (cm)	Pollution monitor sensor 1	Pollution monitor sensor 2	Average value (PPM)
1.	4	2.69	2.69	2.69
2.	5	2.47	2.46	2.46
3.	6	2.08	2.08	2.08
4.	7	1.79	1.79	1.79
5.	8	1.58	1.59	1.58

6.	**9**	1.41	1.41	1.41
7.	**10**	1.26	1.28	1.26
8.	**11**	1.18	1.18	1.18
9.	**12**	1.08	1.08	1.08
10.	**13**	1.00	1.00	1.00

Table 1.Sensor testing results

PPM	Level(m)
2.8	0.00
2.5	0.8
2.1	1.3
2.0	1.6
1.95	1.8
1.7	2.2
1.53	2.5
1.42	2.7
0.8	3.8

Table2. The relationship between the Height and ppm

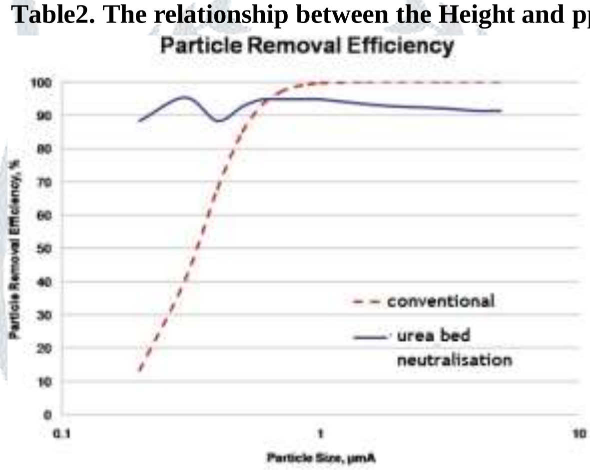

Fig 2.Efficiency Graph

8. CONCLUSION

All the calculations and selection that had been done to make toxic gases absorption easy effective. The urea solution and ceramic balls packing increases liquid-gas contacting surface area thereby increasing toxic gases removal efficiency. Engineering is the application of science to design, plan, construct and maintain manufactured things or converting resources for the benefit of mankind. This should be done efficiently for maximum benefits to be achieved. In line with this engineering opinion, this project was motivated by the need for the pollution control board to keep the environment clean. This ultimately has a positive impact on the rocket engine test facility.

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