

Parametric Analysis on the Erosion and Corrosion Behavior of GRP's Hybrid Composite Pipes Used for the Transport of Petroleum Waste-water

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Abstract Cast iron and concrete are only two examples of the various materials that glass fiber-reinforced polymers (GFRP) are a strong substitute for. It is distinguished by having strong erosion and corrosion resistance and high corrosion resistance. Commercial GRP was utilized in erosion and corrosion tests. It is well-known for being installed in the severe environment of petroleum fields' effluent. This kind of GRP material was put through a simulation of an inclement, or severe, climate. A large number of experiments were conducted: fifteen liters of water were mixed with four different amounts of abrasive sand (200 gm, 250 gm, 300 gm, and 350 mg) of 65 μm diameter. The resulting mixture of abrasive agents is struck by GRP samples that were taken from the walls of cylinder pipes at three different angles—85, 90, and 95 degrees—as well as two different flow rate conditions. Also, the effect of the diameter of the nozzle from which the fluid is projected is investigated by using three different nozzle diameters: 0.25, 0.375, and 0.5 inch. The effect was also investigated when a 5% weight of chlorine was added to the sample. Additionally, the same tests were run for one, two, three, and four hours at different times. The amount of abrasive sand and the flowrate both increased the erosion rate, according to the results. The amount of weight loss, which served as an indication of erosion activity, was shown to have a significant impact on the corrosion rate. Therefore, in hostile environments or in situ situations, GRP provided higher erosion and corrosion protection than traditional materials.

Keywords: GRP's composite pipes, erosion rate, petroleum waste-water, hostile environments, flow characteristics

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1. Introduction

Oil pipelines often break due to corrosion and erosion. Combined pipe corrosion and erosion degrade materials. Sludge abrasion, soil particles, granules, and liquids impacted by mechanical and chemical action form droplets, bubbles, cavitations, or fast-flowing fluids [1]. FRP is lightweight, especially for Young's modulus and impact resistance. Polymer composites are ideal for commercial and military aircraft. Sometimes reinforced polymers fail due to stress corrosion and failure, thus the environment should be investigated.

Glass fiber reinforced polymer is known as GFRP. It is incredibly light and powerful. It is an extremely adaptable material with a wide range of uses in many different

industries, including building, aerospace, and even household use. It offers good mechanical characteristics that are beneficial for a variety of industrial applications.

Glass fiber reinforcement is added to polymer constructions by combining thermosetting resin with either long or short glass fibers. utilized as reinforcement sometimes. These matrices and multilayer polymers are used to make fiberglass reinforced pipelines [2]. Copper pipes cost more than polymer composite pipes. Metallic pipes are forbidden in situations where there is a significant risk of corrosion, erosion, weight, and environmental damage [3]. Because fiberglass-reinforced pipes have a higher specific strength, they may be utilized for piping and water transportation. Transmission above and below ground was studied before room temperature water was studied.

GRP erosion and corrosion were studied using in situ or

severe scenario simulations by Hassan, M.K. et al. [4]. They mixed 0.015 m³ water with 250, 400, and 500 g of 65 µm abrasive sand. Samples of abrasive sand were obtained 90 degrees from cylinder tube walls. Researchers used 10% chlorine at 0.01 m³/min, 0.0067 m³/min, and 0.01 m³/min. Similar tests were done at 1, 2, 3, 4, and 5 hours. They found that flow rate and abrasive sand accelerated erosion. Erosion surpassed three at 0.015 m³ chlorine per 500 g sand. The same conditions caused corrosion's peak. The erosion impact—determined by weight loss—strongly affects corrosion, the study revealed. They found that GFRP resists erosion and corrosion better under severe environments.

Eugene Medvedovski *et al.* [5] compared hard boronized coating on carbon steel achieved by thermal diffusion with two iron boride layers (FeB and Fe₂B) in synergistic erosion-abrasion-corrosion circumstances imitating oil production to bare steel. Custom wear testing equipment was made. Their experiment subjected tubular sections' inner surfaces to high-velocity erosive flows of water-oil slurries with silica sand and salts and steel pony rod rotation and oscillation. The researchers conducted surface structural investigation and profilometry following wear testing. They concluded that due to its high hardness, chemical inertness, dual-layer design, and diffusion-induced substrate bonding, the iron boride coating outperformed bare carbon steel in abrasion and erosion-abrasion-corrosion conditions. In the most critical situations, boronized steel tube and casing with inner surface protection works well.

Qunfeng Zeng and Wenchuang Qi [6] simulated elbow erosion-corrosion in critical chemical equipment using COMSOL multi-physics finite element modeling software. Electrochemical corrosion, solid particle erosion, chemical reaction, and turbulent flow interact. They suggested particle count to explain erosion. The modeling findings indicate that particles with high turbulence intensity immediately impact the elbow wall, creating a tilted elliptical erosion zone at 40-50° on the extrados surface. Due to differences in material concentration distribution, chemical reactions in turbulence cause varying corrosion current densities in the tube. The elbow's extrados surface received 1/6 of the discharged particles.

Fatima Alabtah *et al.* [7] studied hybrid steel/GFRP composite pipes under strong corrosive environments for lengthy periods. The specimens were submerged in intense hydrochloric acid, sodium chloride, and sulfuric acid solutions for up to a year. SEM, XRD, and EDX were used for qualitative analysis. Hybrid pipes have a corrosion rate of less than 1% of ordinary steel pipes. Due to increasing absorption and saturation moisture in the material with prolonged soaking time, the GFRP layer forms pores, resulting in reduced corrosion. The authors suggested a more regulated protective layer fabrication procedure to limit or prevent this. These encouraging results suggest using GFRP protection layers in innovative corrosion-controlling designs.

Using both computational and experimental techniques, Khan et al. [8] studied the impact of sand fines velocity on erosion-corrosion in AISI 1018 carbon steel 90° elbows under liquid-solid flow conditions. Sand fines with a mean diameter of 50 µm were examined using a flow loop at 0.5, 1, and 2 m/s. Material loss analysis, discrete phase

modeling (DPM), multilayer paint modeling (MPM), microscopic imaging, CFD, and DPM were used to understand erosion-corrosion and deterioration. Compared to low transport velocity, increasing slurry velocity affects particle-wall impaction and doubles elbow bottom material deterioration. They observed that erosion pits and scars on the elbow's inside surface control carbon steel wear and promote downstream erosion and corrosion. Pitting and plastic deformation replaced cutting when sand particle transit velocity increased from 0.5 to 2 m/s.

Abradant particle size and concentration affect carbon steel erosion-corrosion, according to Rasse et al. [9]. Researchers conducted degradation studies in a jet erosion-corrosion cell capable of 4.8 m/s flow rate and 30° and 90° jet angles. Abradant particles were angular alumina powder with average sizes of 181, 219, and 359 µm. Experimental data suggests a threshold flow velocity of 2.5 m/s for particles of 181 µm and 45° jet angles. Dissolved dioxygen enhanced degradation rate compared to stagnation without erosion. A 45° jet angle resulted in a maximum erosion-corrosion rate of 4 mg × cm⁻² × h⁻¹, independent of particle size. Abradant concentration enhanced degradation regardless of jet angle. At 45° and 90°, degradation rates plateaued at 7 mg × cm⁻² × h⁻¹ and 5 mg × cm⁻² × h⁻¹, respectively. Degradation slows at a specific concentration, showing dense fluid particle behavior impacts material degradation. Particle interactions in concentrated liquids diminish kinetic energy and explain this critical concentration by affecting flow and metal surface trajectories.

Nishizaki researched toughness and water. GFRP's underwater flexural strength was lower than ambient [3]. Bergman controlled sodium chlorate polymer breakdown. Metals and polymer erosion corrosion were examined to identify polymer processing industry applications.

Aluminium alloy AA5052 was tested for corrosion and attack in a slurry containing 3.50% NaCl by weight and silica as the attack particle [10]. Soil concentrations were 90.0 g/l, solution jet speed was 3.0 m/s, and impact angle was 25.0° to 90.0°. In erosion and corrosion studies, cathodic shielding samples maximize wear rates. Erosion and corrosion peak at 30.0° effect angle. In key conditions, fine corrosion flow has a substantially higher corrosion rate than scour corrosion flow. Also, corrosion at different exposure angles is negligible.

Biocompatible, biodegradable magnesium alloys are safe. They are medicinal materials due to their metallic and mechanical qualities. This material has lesser corrosion resistance than others utilized in physiological or saline situations. They are frequently less useful as biomaterials due to biomechanical inefficiency. Anodizing, surface treatment, coating, pre-treatment, micro-arc oxidation, and electro-deposition address this issue. Mechanical and electrochemical features of biocompatible and biodegradable magnesium alloys are studied here to increase corrosion resistance in physiological and saline settings. Surface-modified (Mg) alloy corrosion and fatigue reasons are also explained [10].

S. Sivasankaran and colleagues measured e-glass mat and woven glass FRP by hand-laying pipes and making several samples for tensile and bending testing. CNC machines and PCD cutting tools were used for the trials. E-glass fabric and mat samples have process

characteristics such feed rate, cutting speed, depth of cut, and workpiece type. The two tubes are filament-wound. Pipes include 30% glass fiber and 70% epoxy polyester resin. Mat and woven E-glass fiber reinforced composites were compared. Physical, chemical, and mechanical properties were ascribed by ASTM [11].

In the work in hand, different parameters are to be investigated for their effect of both erosion and corrosion in GRP pipes.

2. Materials and Methods

2.1. Material

Table 1 demonstrates the use of glass-fiber reinforced polymer pipes with a heterogeneous structure made up of matting, sand, and roving unsaturated polyester resin in the current experiment. Unsaturated polyester resin joins pipe fibers, making them chemical- and environment-resistant. Unsaturated polyester is used to create GRP pipe, which is cheaper but has somewhat higher strength and chemical resistance. For low-pressure applications, it's cheaper. Traditional filament winding was utilized to make composite glass fiber pipes. Layers cover the GRP's intricate structure inside and out. The manufacture method is outlined in [12]. Quartz sand is introduced between the barrier and chaff layers on the exterior and interior surfaces to form the structural layers. Composite material quality depends on manufacturing method, layer thickness, fiber pretension, and fiber form. The ASTM D3171-99 standard and ignition removal process determined these component compositions [13]. Petroleum industries employ these chemical waste pipeline pipes. Table 2 lists composite glass fiber pipe (GRP) elastic characteristics. The pipes used in this experiment were removed after a while. GRP composite roll density was 2.15 g/cm³.

These very tiny threads are woven together to create a flexible fabric. Since GFRP is a molded product, it needs to be placed either inside or outside of the required shape for the object. The most widely used matrix materials are polyester thermosetting resin, epoxy, or vinyl ester. To improve wear resistance, GFRP composites can be reinforced with quartz or aluminum oxide. Polymers reinforced with glass offer a wide range of applications. Because of its resilience to chemicals, it is often employed in water pipelines and other situations where PVC is undesirable. Fiberglass, or fiberglass-reinforced polymers, are widely used in sports equipment like kayaks and nets, but also have a broad range of additional applications in the automotive, aerospace, and other sectors. The current experiment employed random matt unsaturated polyester resin, sand, and hetero-structure glass fiber reinforced polymer pipes of roving, in accordance with the values shown in Figure 1 and documented in Table 1. Polyester resin creates a tubular structure that is resistant to weather and chemicals by binding the fibers together. GFRP pipe may be made with unsaturated polyesters, which are less costly than other resins. Despite the fact that they provide a little boost in strength and chemical resistance.

Table 1. Composition of GFR pipes [14,16]

Constituents	Average %	Viscosity/cp. 25 °C	Thermal Deformation Temperature/°C	Tensile Strength (MPa)	Specific Density (g/cm ³)
Thermosetting unsaturated polyester (Matrix)	30.2%	400	70	65	1.12
Roving	11.8	-----	-----	3100-3400	2.5
matt	13.5	-----	-----	-----	2.66
sand	44.5	-----	-----	-----	2.15
GRP	100	-----	-----	21.5 [23]	2.15

Table 2. Elastic properties of GRP [17]

Properties	E1 (GPa)	E2 (GPa)	ν_{12}	G12 (GPa)	G13 (GPa)	G23 (GPa)
value	100	9	0.3	3.2	3.2	4

2.2. Testing Equipment

The erosion/corrosion testing apparatus was constructed as shown in Figure 1. It is made up of two steel super constructions supported by four columns that are welded at each corner. Inside are the test chamber, agitator, controls, and pump. The top contains the test chamber, a 40 x 40 x 40 cm cubic box with a three-jaw chuck to hold the sample and expose it to the water flow. The walls are attached to the steel beams and columns using super glue, which is subsequently covered with silicone to prevent cracking. The walls are made of acrylic glass, often referred to as methyl methacrylate, on four sides, which provides exceptional transparency for experiment viewing. The device comprises a cylindrical basin for mixing water and sand that measures 30 cm in diameter and 50 cm in height. An electric mixer mixes water and sand in the basin's middle. The water-sand mixture passes through the conduit directly to the pump. The electric water pump raises the mixture's flow rate before sending it to the flow meter and nozzle. The flow meter is used to measure the volumetric fluxes, both linear and non-linear. The nozzle directs the mixture of water and sand into a linear stream. The water falls into the basin after losing momentum and velocity when it reaches the sample. This system is closed in this circuit. As advised in publications [14-16], the samples were extracted from the cylinder wall using a diamond cutter to prevent sample damage and delamination. The rectangular samples had an average dimension of 17 × 14 mm.

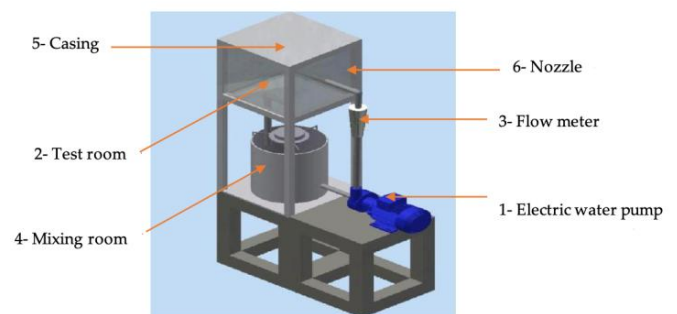


Figure 1. Testing device

2.3. Experimental Parameter

Table 3 below shows the different testing parameters and their used values in the experiments.

Table 3. Experimental Conditions

Parameter	Values			
Flow rate (l/min)	6	10		
Nozzle diameter (inch)	1/4	1/2	3/8	
sand concentration (gram)	200	250	300	350
Angle of Hitting	85 °	90 °	95 °	
Time of hitting (hrs.)	1	2	3	4
Chlorine addition	0%	5%		

2.4. Evaluation of Erosion Rate

Weight loss is employed as the measure of erosion rate resulting from fluid flow over the specimens' surface.

According to Eqn. 1, the erosion rate E can be calculated as follows:

$$E = \frac{\text{weight loss due to erosion}}{\text{time taken to erode}} = \frac{W_{\text{loss}}}{T} \quad (1)$$

The area exposed to erosion At for the material is calculated using Eqn. 2 as follows:

$$At = \frac{\pi}{\sin \alpha} \quad (2)$$

where the impact angle is α . Additionally, using Eqn. 3, the following relationship between weight loss and corrosion is discovered:

$$\text{Corrosion rate} = Cr = \frac{\text{weight loss due to erosion}}{\text{time taken to erode}} = \frac{K \times w}{D \times At \times T} \quad (3)$$

Where K constant (876×10^4), T is Time Exposure (hours), w is weight loss, and D material density (GRP density was listed in Table 1).

$$W_{\text{loss}(i)} = \sum_{i,j} (w_{i-1} + w_j) \quad (4)$$

Where $i=1,2$ to 5, $j=1, 2, 3$ to 5 the two adjacent hours.

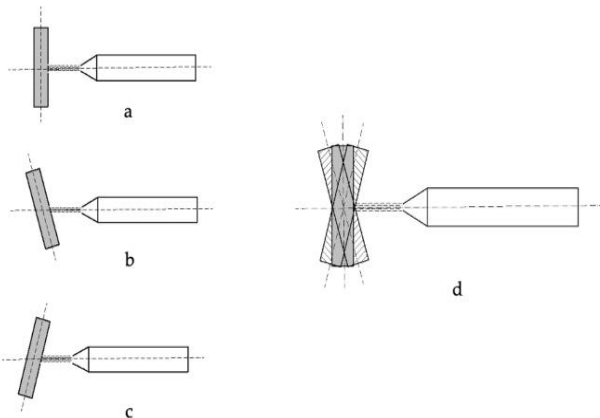


Figure 2. Nozzle inclination angles (a) right angle 90° - (b) obtuse angle 95° - (c) acute angle 85° (d) Incident angle changes used in experiments

The effect of the parameters listed in Table 3 were tested through carrying out 304 experiments with different testing conditions to be able to study the effect of these parameters on the cumulative weight loss which was determined based on equation 4 and the corrosion rate in the test specimen.

Figure 2 shows the directions of the flow incident angle onto the specimens which were used in the experiments to study the effect of nozzle inclination; three nozzle inclination angles were used, namely, 85°, 90°, 95° as mentioned in Table 3.

3. Results

The whole erosion/corrosion test data for each combination of test parameters is included in Tables 4 and 5 in the appendix. The sample that was eroded with 250 g of sand at a rate of 10 l/min had an erosion rate of 1.15% at its highest, whereas the sample that was eroded at a rate of 6.67 l/min had an erosion rate of around 0.05%. This resulted from the sample's initial lower strength of the reinforcing phase, which caused the values to corrode. When it came to erosion conditions, there was a negative indication at 10 l/min + 10wt. This is due to the fact that the bonding of the silica sand particles utilized in the production of GRP pipes is greatly impacted by chlorine. Water can seep into the spaces created between the sand particles because of the epoxy resin's chemical reaction with the chlorine. According to Abdellah et al. [14], this is why their weight increases at shallow depths of the ablated surfaces following the test. However, in bigger damaged sand patches of 400 or even 500, this phenomenon vanished because the fast rate of erosion in these conditions did not allow the material to retain water inside.

Test results are illustrated using ANOVA interaction plot using Minitab software. The resulted graphs are shown in the following set of figures.

Hereby, the experiments are devoted to reveal the effect of petroleum wastewater flow parameters on the erosion corrosion wear of GRP's composite pipes. As mentioned in Table 3 before, many parameters were investigated, namely, flow rate which values were 6 and 10 L/min, Nozzle diameter of 0.250, 0.375, and 0.500 inch. Four values of sand concentration were used, 200, 250, 300 and 350 gm per 15 Liter of water. To study the effect if incident angle (hitting angle) three variations of angles were used, acute, right and obtuse angles with the values of 85°, 90° and 95° were used. The experiments combinations of parameters were conducted for periods of time of 1, 2, 3 and 4 hours each. And in order to investigate corrosion in addition to erosion, chlorine was added to the fluid with 5% concentration for some experimental parameters. The results of the conducted experiments are interpreted in the following sections

3.1. Effect of Flow Rate

When various test parameters are used, such as nozzle diameter (Figure 3), injection time (Figure 4 and 5), incident angle (Figure 10 and 11), or sand particle concentration (Figure 16 and 17), the results show that flow rate has a significant impact on cumulative weight

loss and erosion rate. It is evident from each of these situations that the erosion rate and cumulative weight loss both rise with flow rate. This makes sense since when the flow rate increases, the impact velocity increases as well. This is explained by the fact that abrasive sand at high velocity produces enormous momentum and high kinetic energy, which impacts the sample surfaces and erodes the weaker layers. As a result, material loss results from an increase in the number of impact sites caused by an increase in sand quantity.

3.2. Effect of Nozzle Diameter

Figures 6 and 7 presents the effect of the nozzle diameter on the erosion rate and on the cumulative weight loss respectively. The test results show that as the nozzle diameter decreases, both the erosion rate and the cumulative weight loss increase this is due to that decreasing nozzle diameter leads to the increase of velocity, hence kinetic energy resulting in higher removal rate.

3.3. Effect of Incident Angle

It was observed that the incident angle has an effect on both cumulative weight loss and erosion rate, figures 8 and 9. As shown in figures 10, 11, 12 and 13 the cumulative weight loss and erosion rate reaches their maximum values in the case the flow is perpendicular to the specimen surface and these values decrease as the angle of incidence either increased or decreased. But it worth noting that from the results it can be observed that decreasing the angle to 85° (acute angle) resulted in obtaining cumulative weight loss and erosion rate larger than the case of increasing the angle to 95° (obtuse angle). This can be explained that as the flow strikes the surface at an obtuse angle the flow smoothly slides over the surface leading to less kinetic energy exchange and hence less effect of the energy on the surface resulting in less erosion rate. This needs more investigations in future work by inspecting the effect of different angles of incidence and the amount of energy within the process.

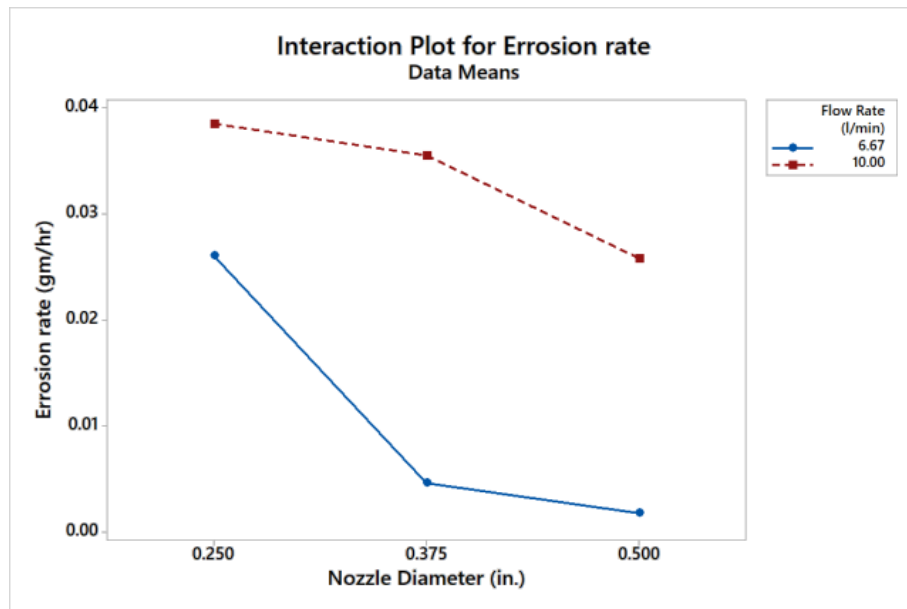


Figure 3. Effect of Nozzle Diameter on Erosion rate for different Flow rates

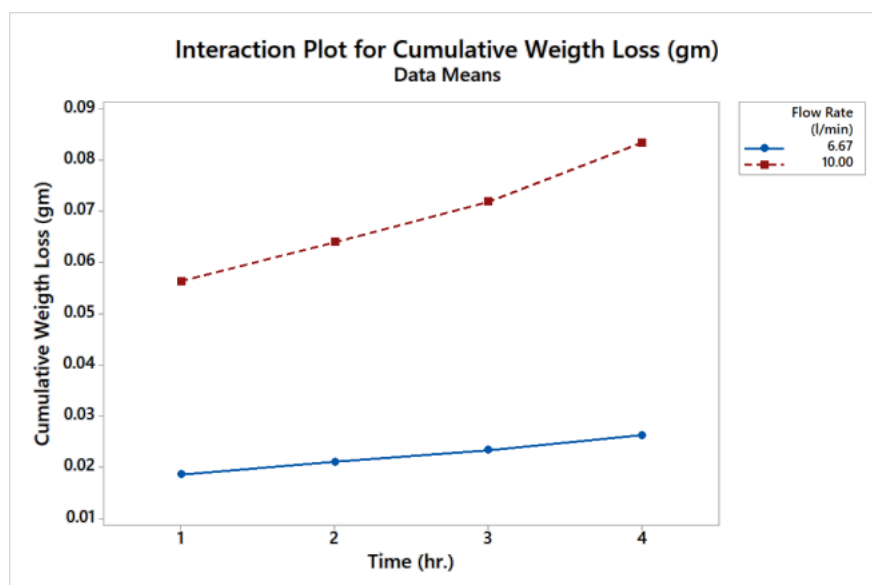


Figure 4. Effect of Injection Time on Cumulative weight loss for different Flow rates

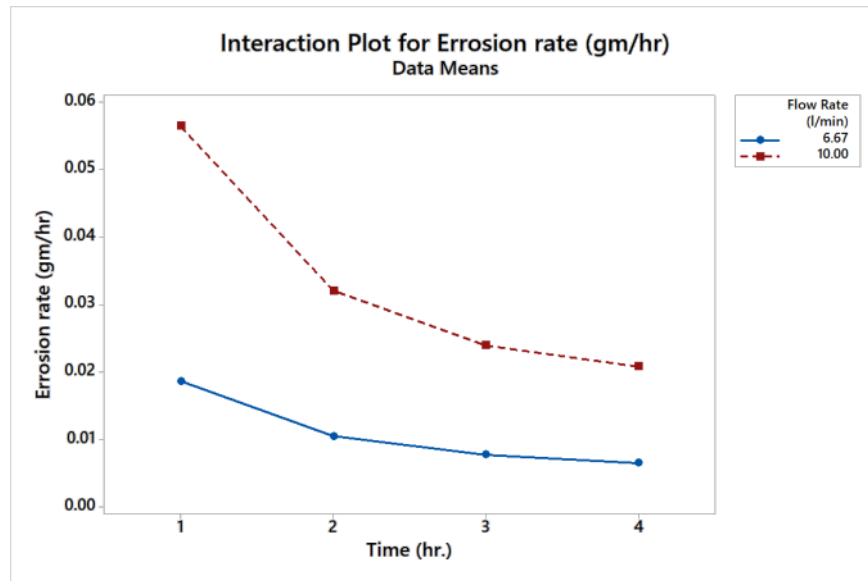


Figure 5. Effect of Injection time on Erosion rate for different Flow rates

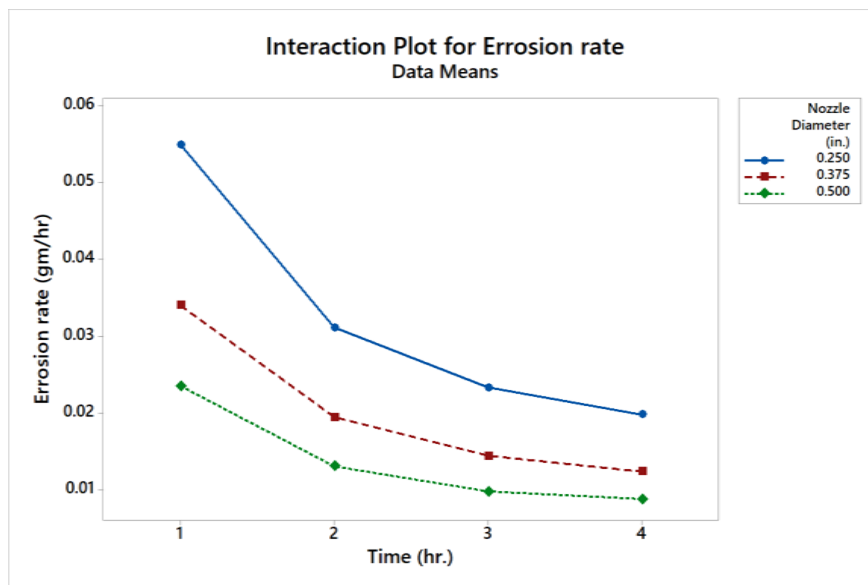


Figure 6. Effect of Injection Time on Erosion rate for different Nozzle Diameters

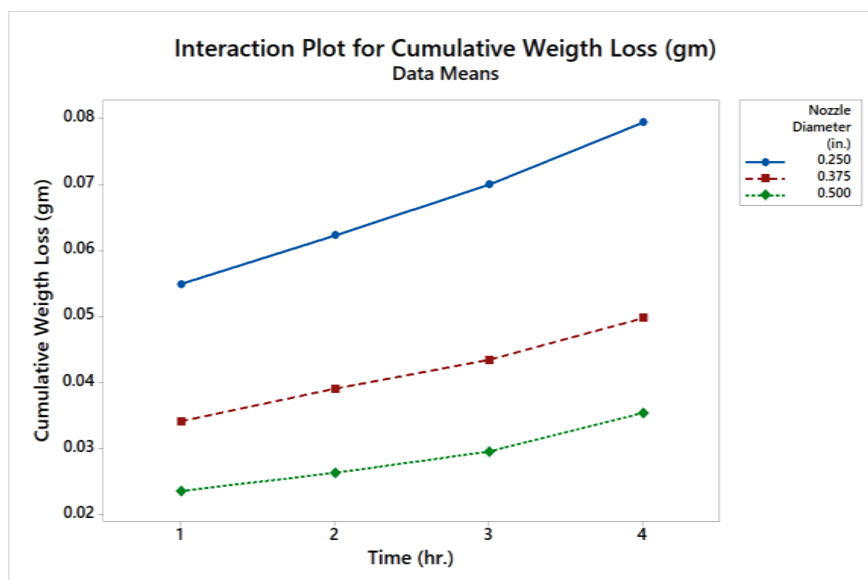


Figure 7. Effect of Injection Time on Cumulative weight loss for different Nozzle Diameters

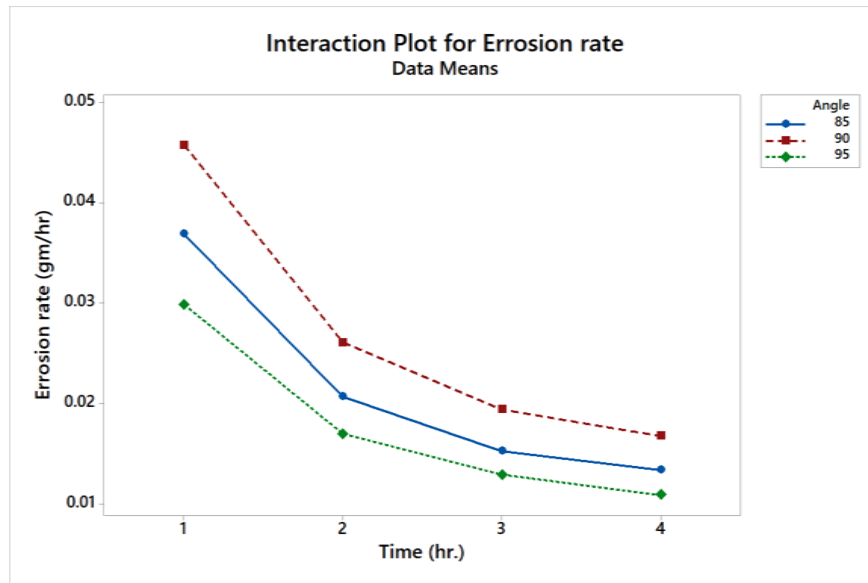


Figure 8. Effect of Injection Time on Erosion rate for different incident angles

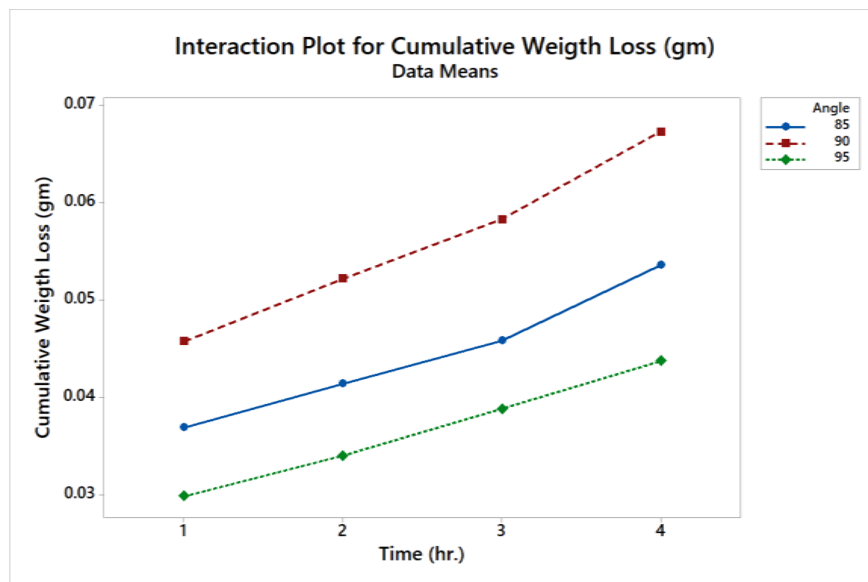


Figure 9. Effect of Injection Time on Cumulative weight loss for different incident angles

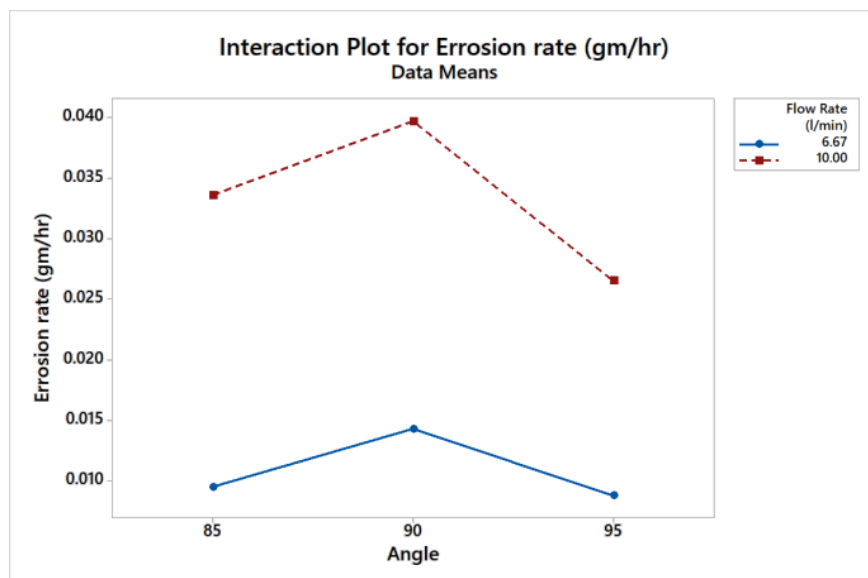


Figure 10. Effect of incident angle on Erosion rate for different Flow rates

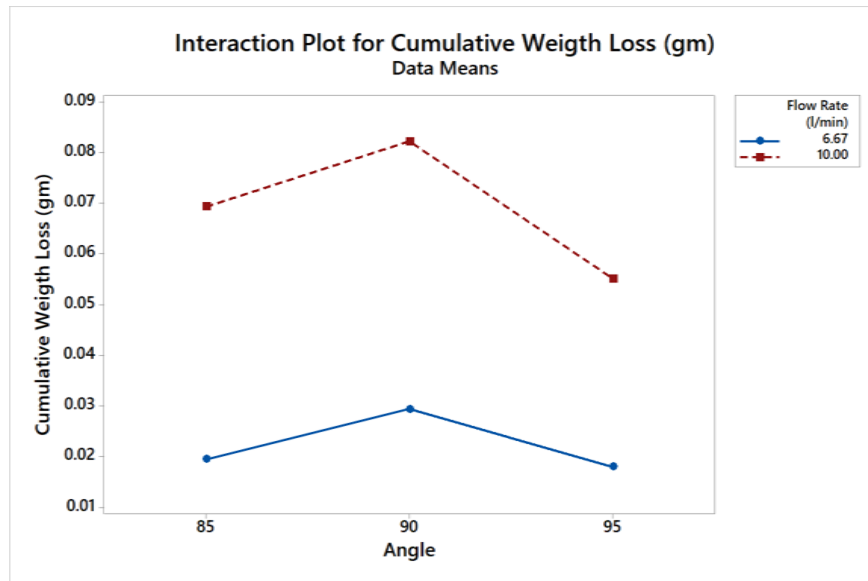


Figure 11. Effect of incident angle on Cumulative weight loss for different Flow rates

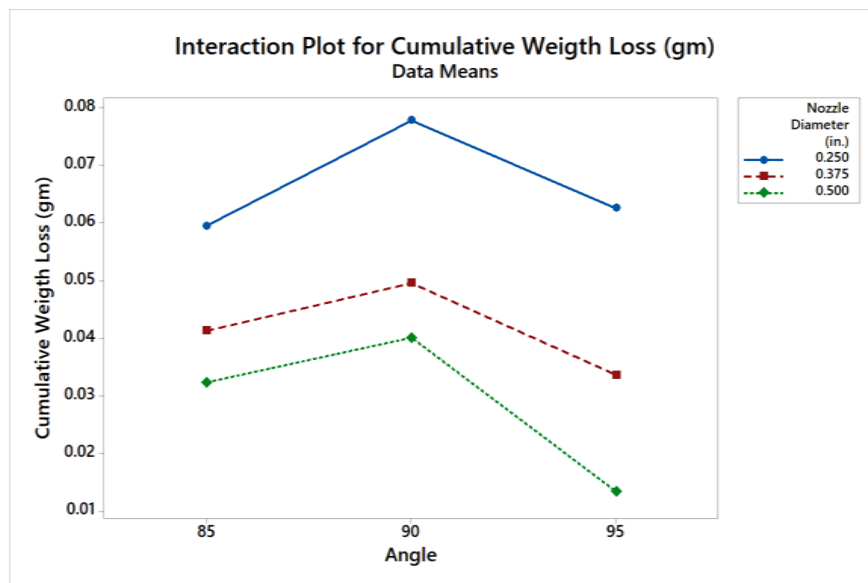


Figure 12. Effect of incident angle on Cumulative weight loss for different Nozzle diameters

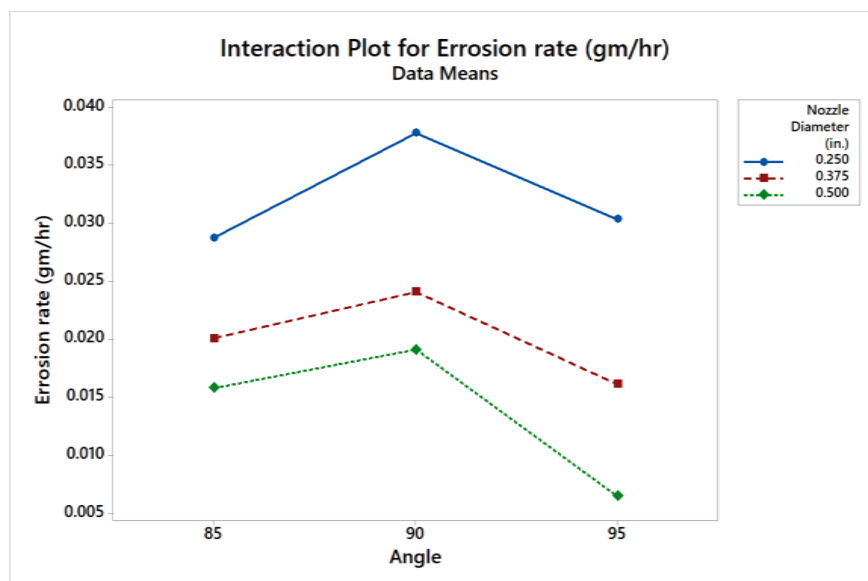


Figure 13. Effect of incident angle on Erosion rate for different Nozzle diameters

3.4 Effect of Sand Concentration

Figures 14, 15, 16 and 17 show the effect of sand concentration on both cumulative weight loss and erosion rate. It is obvious that increasing sand concentration leads to increasing cumulative weight loss. Also, it worth noted that the effect of increasing sand concentration greatly affects the cumulative weight loss and erosion rate at higher flow rate than at lower flow rate. This can be explained by the effect of higher flow rate resulting in higher kinetic energy specially in case to high sand concentration.

Figures 18 and 19 present the main effect of different test parameters of the cumulative weight loss and the erosion rate respectively. It is clear from Figure 19 that the cumulative weight loss is directly proportional to the

values of flow rate, time and sand concentration while adversely proportional to the values of nozzle diameter. Whereas the cumulative weight loss reaches its maximum in case of a right incident angle having lower amount in case of acute angle and a minimum value for obtuse angle.

Similar trends can be observed from Figure 20 which depicts that the erosion rate is directly proportional to the values of flow rate and sand concentration while adversely proportional to the values of nozzle diameter and time. Whereas the cumulative weight loss reaches its maximum in case of a right incident angle having lower amount in case of acute angle and a minimum value for obtuse angle.

The following Figure 20 (a and b) shows the interaction of all test parameters with the cumulative weight loss and erosion rate respectively.

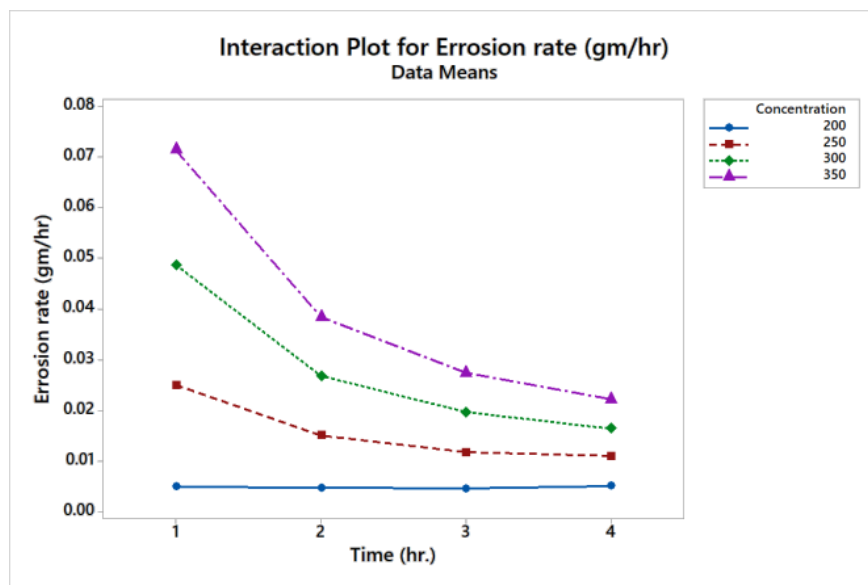


Figure 14. Effect of Injection time on Erosion rate for different sand particles Concentration

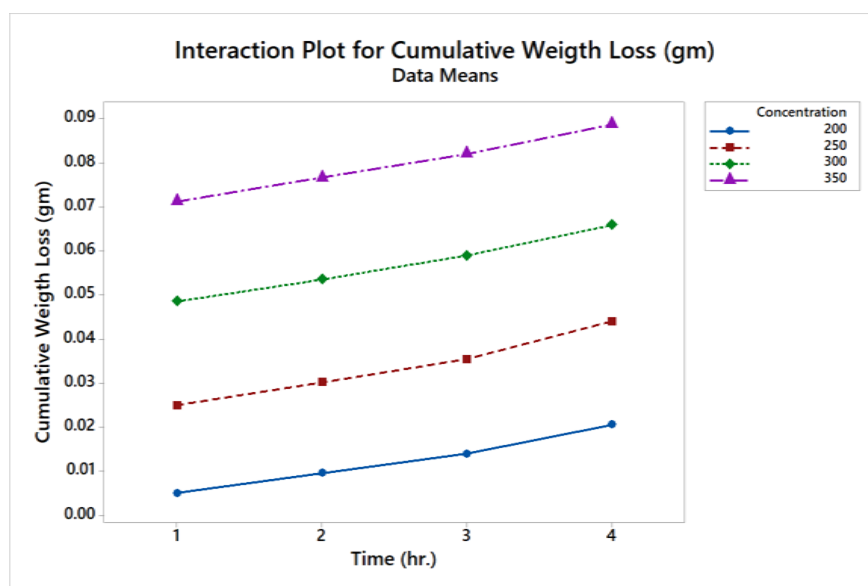


Figure 15. Effect of Injection time on Cumulative weight loss for different sand particles Concentration

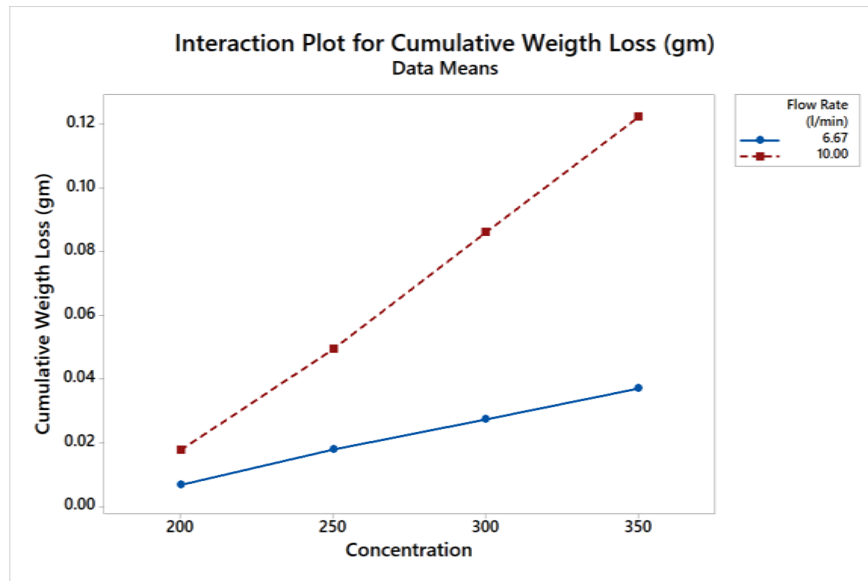


Figure 16. Effect of sand particles Concentration on Cumulative weight loss for different Flow rates

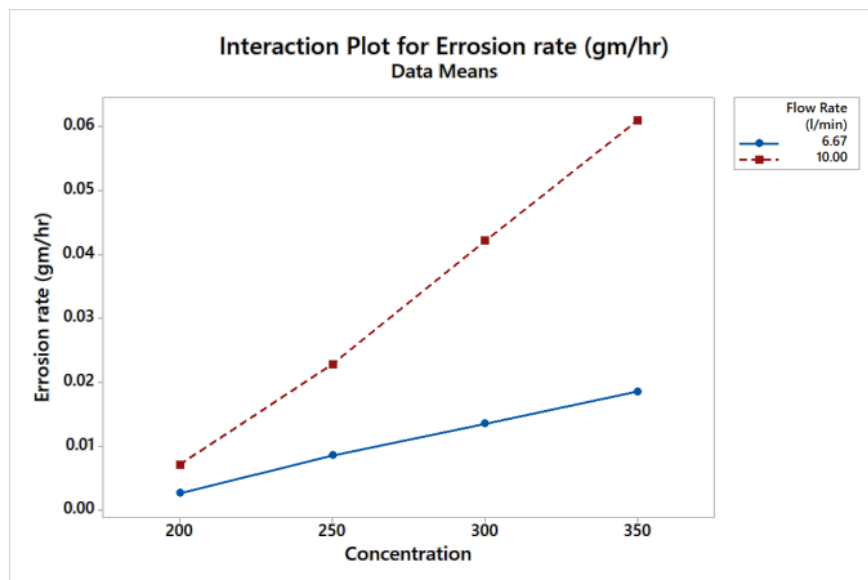


Figure 17. Effect of sand particles Concentration on Erosion rate for different Flow rates

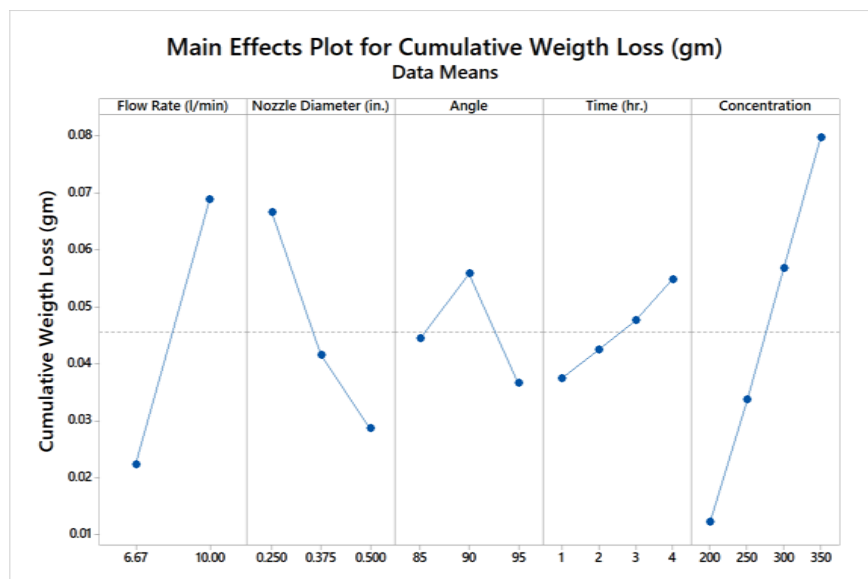


Figure 18. Main effect of different parameters on cumulative weight loss

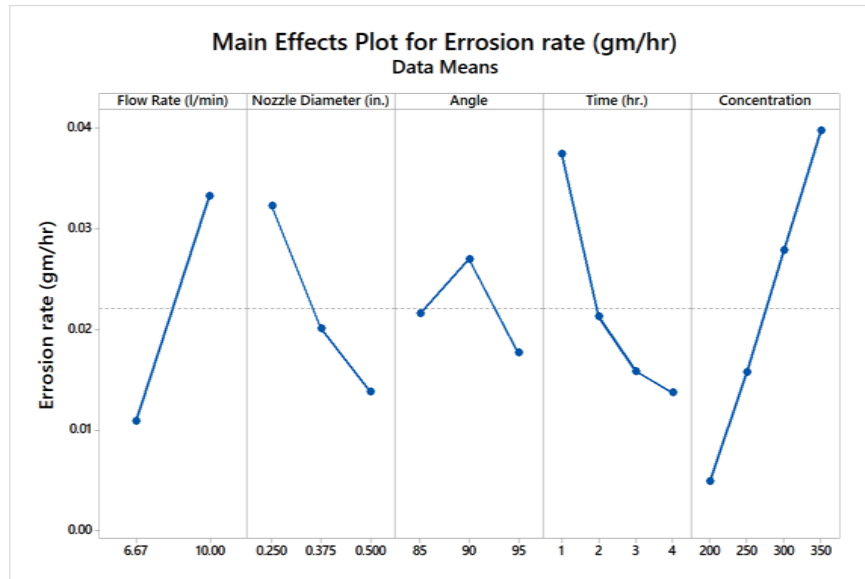
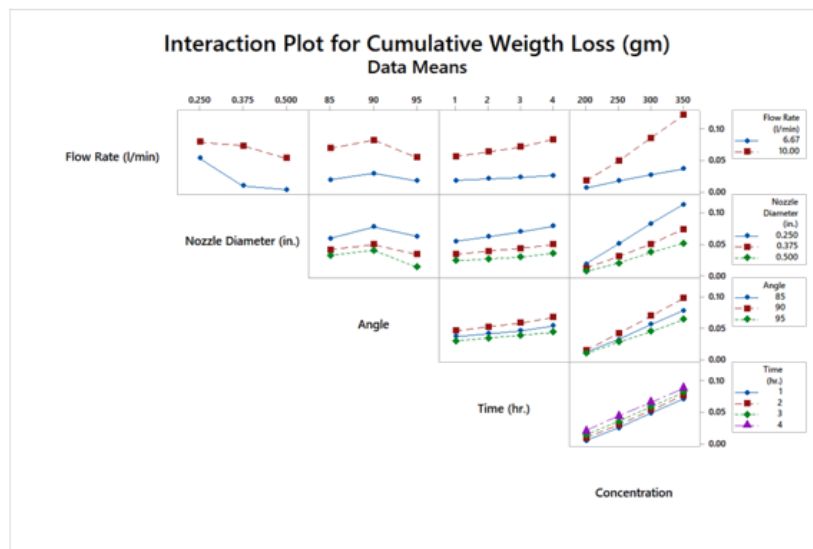
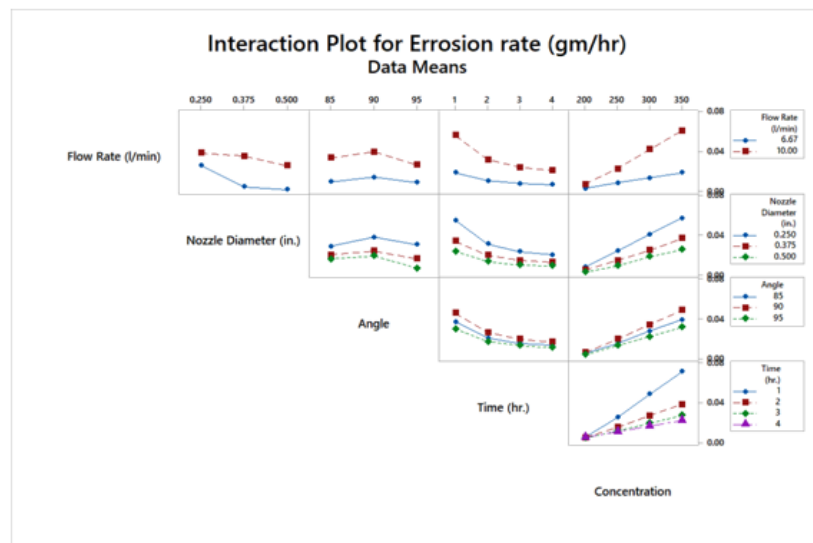


Figure 19. Main effect of different parameters on erosion rate

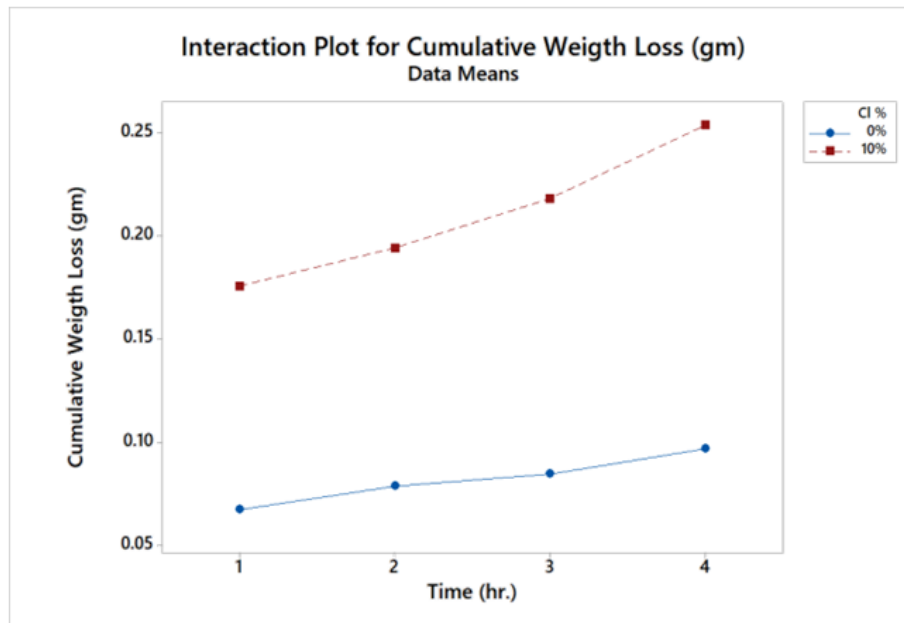


(a)

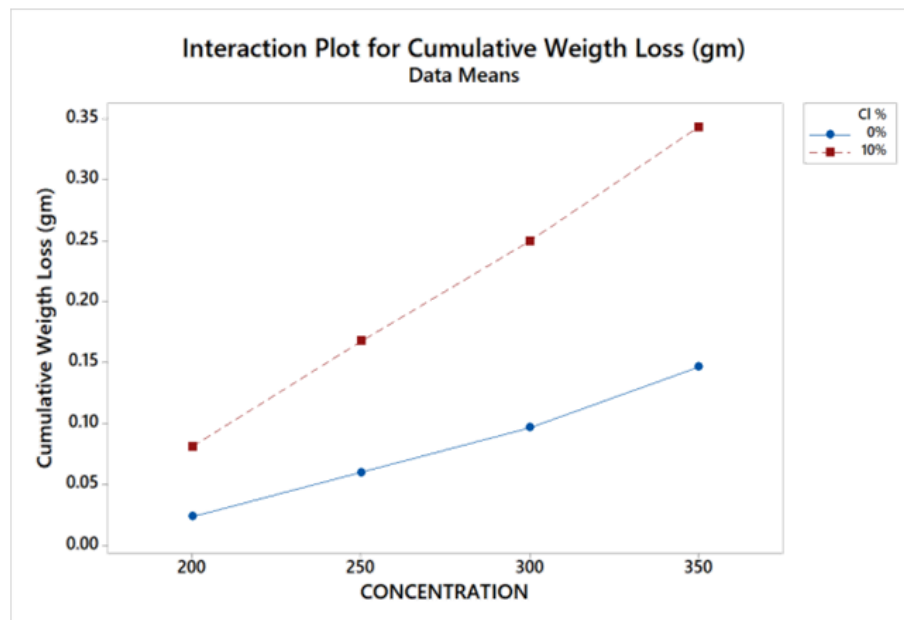


(b)

Figure 20. Interaction plots using ANOVA showing the contribution of all test parameters to the cumulative weight loss and erosion rate



(a)



(b)

Figure 21. Effect of adding 10% Cl

3.5. Effect of Adding Chlorine

Figure 21 (a and b) illustrates the effect on cumulative weight loss in case of adding 10% Chlorine to emulsion. In both figures, a comparison between the cases with and without adding CL. It can be seen that adding 10% Cl leads to increasing the cumulative weight loss. The effect of adding CL increases at higher sand concentration as seen in Figure 21 b.

4. Conclusion

Today's robust and competitive substitute for metals, particularly steel, are GRP pipes, due to their exceptional resistance to erosion and corrosion. It was thoroughly

qualified to study the erosion/corrosion behavior of GRP material put in a tough environment. The concentration of sand and the flow rate of the erosive fluid both had a significant impact on the rate of erosion. The erosion rate was shown to increase with the amount of abrasive grit present in the fluid. The amount of abrasive sand and the GRP material's degradation and corrosion were strongly correlated. Chlorine's influence on the corrosion and erosion behavior of the material was discovered here, as it has been proven to have a substantial effect on corrosion in prior study. Also, as a result from this research, in the design of the pipe fittings, it is better to use elbows with obtuse angle rather than right or acute angles as in this case the erosion will be less. Also, try to avoid reducing fittings diameters as this will result in higher flow rates and hence higher erosion in the pipes.

Appendix A

Table 4. Experimental conditions and results

specimen no.	Flow Rate (l/min)	Nozzle Diameter (in.)	Angle	Time (hr.)	Sand Concentration (gm/15 L water)	Final Weight (gm)	Original Weight (gm)	Weight Loss (gm)	Cumulative Weight Loss
1	6.67	1/4	85	1	200	3.2210	3.2280	0.0070	0.0070
2	6.67	1/4	85	2	200	3.2280	3.2320	0.0040	0.0110
3	6.67	1/4	85	3	200	3.2320	3.2380	0.0060	0.0170
4	6.67	1/4	85	4	200	3.2380	3.2450	0.0070	0.0240
5	6.67	1/4	85	1	250	2.6670	2.6720	0.0050	0.0290
6	6.67	1/4	85	2	250	2.6720	2.6770	0.0050	0.0340
7	6.67	1/4	85	3	250	2.6770	2.6820	0.0050	0.0390
8	6.67	1/4	85	4	250	2.6820	2.6890	0.0070	0.0460
9	6.67	1/4	85	1	300	2.7150	2.7200	0.0050	0.0510
10	6.67	1/4	85	2	300	2.7200	2.7250	0.0050	0.0560
11	6.67	1/4	85	3	300	2.7250	2.7290	0.0040	0.0600
12	6.67	1/4	85	4	300	2.7290	2.7370	0.0080	0.0680
13	6.67	1/4	85	1	350	3.4120	3.4160	0.0040	0.0720
14	6.67	1/4	85	2	350	3.4160	3.4200	0.0040	0.0760
15	6.67	1/4	85	3	350	3.4200	3.4250	0.0050	0.0810
16	6.67	1/4	85	4	350	3.4250	3.4310	0.0060	0.0870
17	6.67	1/4	90	1	200	2.8710	2.8790	0.0080	0.0080
18	6.67	1/4	90	2	200	2.8790	2.8900	0.0110	0.0190
19	6.67	1/4	90	3	200	2.8900	2.8950	0.0050	0.0240
20	6.67	1/4	90	4	200	2.8950	2.9100	0.0150	0.0390
21	6.67	1/4	90	1	250	3.1540	3.1600	0.0060	0.0450
22	6.67	1/4	90	2	250	3.1600	3.1680	0.0080	0.0530
23	6.67	1/4	90	3	250	3.1680	3.1720	0.0040	0.0570
24	6.67	1/4	90	4	250	3.1720	3.1780	0.0060	0.0630
25	6.67	1/4	90	1	300	3.2250	3.2320	0.0070	0.0700
26	6.67	1/4	90	2	300	3.2320	3.2390	0.0070	0.0770
27	6.67	1/4	90	3	300	3.2390	3.2440	0.0050	0.0820
28	6.67	1/4	90	4	300	3.2440	3.2520	0.0080	0.0900
29	6.67	1/4	90	1	350	2.9850	2.9910	0.0060	0.0960
30	6.67	1/4	90	2	350	2.9910	2.9970	0.0060	0.1020
31	6.67	1/4	90	3	350	2.9970	3.0060	0.0090	0.1110
32	6.67	1/4	90	4	350	3.0060	3.0150	0.0090	0.1200
33	6.67	1/4	95	1	200	2.9340	2.9390	0.0050	0.0050
34	6.67	1/4	95	2	200	2.9390	2.9450	0.0060	0.0110
35	6.67	1/4	95	3	200	2.9450	2.9500	0.0050	0.0160
36	6.67	1/4	95	4	200	2.9500	2.9550	0.0050	0.0210
37	6.67	1/4	95	1	250	2.8140	2.8240	0.0100	0.0310
38	6.67	1/4	95	2	250	2.8240	2.8300	0.0060	0.0370
39	6.67	1/4	95	3	250	2.8330	2.8390	0.0060	0.0430
40	6.67	1/4	95	4	250	2.8390	2.8420	0.0030	0.0460
41	6.67	1/4	95	1	300	2.7320	2.7380	0.0060	0.0520
42	6.67	1/4	95	2	300	2.7380	2.7410	0.0030	0.0550
43	6.67	1/4	95	3	300	2.7410	2.7480	0.0070	0.0620
44	6.67	1/4	95	4	300	2.7480	2.7510	0.0030	0.0650
45	6.67	1/4	95	1	350	2.8170	2.8220	0.0050	0.0700
46	6.67	1/4	95	2	350	2.8220	2.8290	0.0070	0.0770
47	6.67	1/4	95	3	350	2.8290	2.8340	0.0050	0.0820
48	6.67	1/4	95	4	350	2.8370	2.8390	0.0020	0.0840
49	6.67	3/8	85	1	200	3.2210	3.2220	0.0010	0.0010
50	6.67	3/8	85	2	200	3.2220	3.2228	0.0008	0.0018
51	6.67	3/8	85	3	200	3.2228	3.2230	0.0002	0.0020
52	6.67	3/8	85	4	200	3.2230	3.2240	0.0010	0.0030
53	6.67	3/8	85	1	250	2.8710	2.8720	0.0010	0.0040
54	6.67	3/8	85	2	250	2.8720	2.8730	0.0010	0.0050
55	6.67	3/8	85	3	250	2.8730	2.8739	0.0009	0.0059
56	6.67	3/8	85	4	250	2.8739	2.8750	0.0011	0.0070

specimen no.	Flow Rate (l/min)	Nozzle Diameter (in.)	Angle	Time (hr.)	Sand Concentration (gm/15 L water)	Final Weight (gm)	Original Weight (gm)	Weight Loss (gm)	Cumulative Weight Loss
57	6.67	3/8	85	1	300	2.6550	2.6559	0.0009	0.0079
58	6.67	3/8	85	2	300	2.6559	2.6560	0.0001	0.0080
59	6.67	3/8	85	3	300	2.6560	2.6570	0.0010	0.0090
60	6.67	3/8	85	4	300	2.6570	2.6580	0.0010	0.0100
61	6.67	3/8	85	1	350	3.3350	3.3360	0.0010	0.0110
62	6.67	3/8	85	2	350	3.3360	3.3369	0.0009	0.0119
63	6.67	3/8	85	3	350	3.3369	3.3375	0.0006	0.0125
64	6.67	3/8	85	4	350	3.3375	3.3380	0.0005	0.0130
65	6.67	3/8	90	1	200	2.8880	2.8890	0.0010	0.0010
66	6.67	3/8	90	2	200	2.8890	2.8910	0.0020	0.0030
67	6.67	3/8	90	3	200	2.8910	2.8940	0.0030	0.0060
68	6.67	3/8	90	4	200	2.8940	2.8970	0.0030	0.0090
69	6.67	3/8	90	1	250	3.0120	3.0140	0.0020	0.0110
70	6.67	3/8	90	2	250	3.0140	3.0150	0.0010	0.0120
71	6.67	3/8	90	3	250	3.0150	3.0170	0.0020	0.0140
72	6.67	3/8	90	4	250	3.0170	3.0190	0.0020	0.0160
73	6.67	3/8	90	1	300	2.6650	2.6670	0.0020	0.0180
74	6.67	3/8	90	2	300	2.6670	2.6690	0.0020	0.0200
75	6.67	3/8	90	3	300	2.6690	2.6710	0.0020	0.0220
76	6.67	3/8	90	4	300	2.6710	2.6740	0.0030	0.0250
77	6.67	3/8	90	1	350	2.9810	2.9830	0.0020	0.0270
78	6.67	3/8	90	2	350	2.9830	2.9850	0.0020	0.0290
79	6.67	3/8	90	3	350	2.9850	2.9870	0.0020	0.0310
80	6.67	3/8	90	4	350	2.9870	2.9890	0.0020	0.0330
81	6.67	3/8	95	1	200	2.7420	2.7425	0.0005	0.0005
82	6.67	3/8	95	2	200	2.7425	2.7429	0.0004	0.0009
83	6.67	3/8	95	3	200	2.7429	2.7435	0.0006	0.0015
84	6.67	3/8	95	4	200	2.7435	2.7439	0.0004	0.0019
85	6.67	3/8	95	1	250	3.4560	3.4570	0.0010	0.0029
86	6.67	3/8	95	2	250	3.4570	3.4578	0.0008	0.0037
87	6.67	3/8	95	3	250	3.4578	3.4580	0.0002	0.0039
88	6.67	3/8	95	4	250	3.4580	3.4590	0.0010	0.0049
89	6.67	3/8	95	1	300	2.7890	2.7895	0.0005	0.0054
90	6.67	3/8	95	2	300	2.7895	2.7899	0.0004	0.0058
91	6.67	3/8	95	3	300	2.7899	2.7900	0.0001	0.0059
92	6.67	3/8	95	4	300	2.7900	2.7910	0.0010	0.0069
93	6.67	3/8	95	1	350	3.0120	3.0122	0.0002	0.0071
94	6.67	3/8	95	2	350	3.0122	3.0123	0.0001	0.0072
95	6.67	3/8	95	3	350	3.0123	3.0130	0.0007	0.0079
96	6.67	3/8	95	4	350	3.0130	3.0138	0.0008	0.0087
97	6.67	1/2	85	1	200	2.6690	2.6695	0.0005	0.0005
98	6.67	1/2	85	2	200	2.6695	2.6698	0.0003	0.0008
99	6.67	1/2	85	3	200	2.6698	2.6700	0.0002	0.0010
100	6.67	1/2	85	4	200	2.6700	2.6710	0.0010	0.0020
101	6.67	1/2	85	1	250	3.2230	3.2238	0.0008	0.0028
102	6.67	1/2	85	2	250	3.2238	3.2240	0.0002	0.0030
103	6.67	1/2	85	3	250	3.2240	3.2243	0.0003	0.0033
104	6.67	1/2	85	4	250	3.2243	3.2249	0.0006	0.0039
105	6.67	1/2	85	1	300	3.2240	3.2245	0.0005	0.0044
106	6.67	1/2	85	2	300	3.2245	3.2250	0.0005	0.0049
107	6.67	1/2	85	3	300	3.2250	3.2255	0.0005	0.0054
108	6.67	1/2	85	4	300	3.2255	3.2260	0.0005	0.0059
109	6.67	1/2	85	1	350	2.8420	2.8425	0.0005	0.0064
110	6.67	1/2	85	2	350	2.8425	2.8429	0.0004	0.0068
111	6.67	1/2	85	3	350	2.8429	2.8433	0.0004	0.0072
112	6.67	1/2	85	4	350	2.8433	2.8439	0.0006	0.0078
113	6.67	1/2	90	1	200	2.8810	2.8814	0.0004	0.0004
114	6.67	1/2	90	2	200	2.8814	2.8818	0.0004	0.0008
115	6.67	1/2	90	3	200	2.8818	2.8823	0.0005	0.0013
116	6.67	1/2	90	4	200	2.8823	2.8832	0.0009	0.0022

specimen no.	Flow Rate (l/min)	Nozzle Diameter (in.)	Angle	Time (hr.)	Sand Concentration (gm/15 L water)	Final Weight (gm)	Original Weight (gm)	Weight Loss (gm)	Cumulative Weight Loss
117	6.67	1/2	90	1	250	3.5440	3.5444	0.0004	0.0026
118	6.67	1/2	90	2	250	3.5444	3.5448	0.0004	0.0030
119	6.67	1/2	90	3	250	3.5448	3.5453	0.0005	0.0035
120	6.67	1/2	90	4	250	3.5453	3.5467	0.0014	0.0049
121	6.67	1/2	90	1	300	2.9210	2.9216	0.0006	0.0055
122	6.67	1/2	90	2	300	2.9216	2.9220	0.0004	0.0059
123	6.67	1/2	90	3	300	2.9220	2.9227	0.0007	0.0066
124	6.67	1/2	90	4	300	2.9227	2.9239	0.0012	0.0078
125	6.67	1/2	90	1	350	2.7410	2.7415	0.0005	0.0083
126	6.67	1/2	90	2	350	2.7415	2.7419	0.0004	0.0087
127	6.67	1/2	90	3	350	2.7419	2.7424	0.0005	0.0092
128	6.67	1/2	90	4	350	2.7424	2.7438	0.0014	0.0106
129	6.67	1/2	95	1	200	2.6540	2.6542	0.0002	0.0002
130	6.67	1/2	95	2	200	2.6542	2.6544	0.0002	0.0004
131	6.67	1/2	95	3	200	2.6544	2.6547	0.0003	0.0007
132	6.67	1/2	95	4	200	2.6547	2.6550	0.0003	0.0010
133	6.67	1/2	95	1	250	3.2410	3.2412	0.0002	0.0012
134	6.67	1/2	95	2	250	3.2412	3.2414	0.0002	0.0014
135	6.67	1/2	95	3	250	3.2414	3.2417	0.0003	0.0017
136	6.67	1/2	95	4	250	3.2417	3.2419	0.0002	0.0019
137	6.67	1/2	95	1	300	3.5510	3.5513	0.0003	0.0022
138	6.67	1/2	95	2	300	3.5513	3.5516	0.0003	0.0025
139	6.67	1/2	95	3	300	3.5516	3.5519	0.0003	0.0028
140	6.67	1/2	95	4	300	3.5519	3.5522	0.0003	0.0031
141	6.67	1/2	95	1	350	2.7190	2.7192	0.0002	0.0033
142	6.67	1/2	95	2	350	2.7192	2.7195	0.0003	0.0036
143	6.67	1/2	95	3	350	2.7195	2.7199	0.0004	0.0040
144	6.67	1/2	95	4	350	2.7199	2.7210	0.0011	0.0051
145	10.00	1/4	85	1	200	3.2490	3.2560	0.0070	0.0070
146	10.00	1/4	85	2	200	3.2560	3.2610	0.0050	0.0120
147	10.00	1/4	85	3	200	3.2610	3.2680	0.0070	0.0190
148	10.00	1/4	85	4	200	3.2680	3.2780	0.0100	0.0290
149	10.00	1/4	85	1	250	2.6120	2.6190	0.0070	0.0360
150	10.00	1/4	85	2	250	2.6190	2.6270	0.0080	0.0440
151	10.00	1/4	85	3	250	2.6270	2.6360	0.0090	0.0530
152	10.00	1/4	85	4	250	2.6360	2.6470	0.0110	0.0640
153	10.00	1/4	85	1	300	2.8390	2.8470	0.0080	0.0720
154	10.00	1/4	85	2	300	2.8470	2.8560	0.0090	0.0810
155	10.00	1/4	85	3	300	2.8560	2.8670	0.0110	0.0920
156	10.00	1/4	85	4	300	2.8670	2.8840	0.0170	0.1090
157	10.00	1/4	85	1	350	3.0410	3.0490	0.0080	0.1170
158	10.00	1/4	85	2	350	3.0490	3.0570	0.0080	0.1250
159	10.00	1/4	85	3	350	3.0570	3.0680	0.0110	0.1360
160	10.00	1/4	85	4	350	3.0680	3.0840	0.0160	0.1520
161	10.00	1/4	90	1	200	2.6510	2.6600	0.0090	0.0090
162	10.00	1/4	90	2	200	2.6600	2.6690	0.0090	0.0180
163	10.00	1/4	90	3	200	2.6690	2.6790	0.0100	0.0280
164	10.00	1/4	90	4	200	2.6790	2.6870	0.0080	0.0360
165	10.00	1/4	90	1	250	2.7770	2.7880	0.0110	0.0470
166	10.00	1/4	90	2	250	2.7880	2.7990	0.0110	0.0580
167	10.00	1/4	90	3	250	2.7990	2.8150	0.0160	0.0740
168	10.00	1/4	90	4	250	2.8150	2.8310	0.0160	0.0900
169	10.00	1/4	90	1	300	3.4120	3.4210	0.0090	0.0990
170	10.00	1/4	90	2	300	3.4210	3.4350	0.0140	0.1130
171	10.00	1/4	90	3	300	3.4350	3.4440	0.0090	0.1220
172	10.00	1/4	90	4	300	3.4440	3.4550	0.0110	0.1330
173	10.00	1/4	90	1	350	2.8510	2.8590	0.0080	0.1410
174	10.00	1/4	90	2	350	2.8590	2.8650	0.0060	0.1470
175	10.00	1/4	90	3	350	2.8650	2.8700	0.0050	0.1520
176	10.00	1/4	90	4	350	2.8700	2.8860	0.0160	0.1680

specimen no.	Flow Rate (l/min)	Nozzle Diameter (in.)	Angle	Time (hr.)	Sand Concentration (gm/15 L water)	Final Weight (gm)	Original Weight (gm)	Weight Loss (gm)	Cumulative Weight Loss
177	10.00	1/4	95	1	200	3.3120	3.3210	0.0090	0.0090
178	10.00	1/4	95	2	200	3.3210	3.3290	0.0080	0.0170
179	10.00	1/4	95	3	200	3.3290	3.3380	0.0090	0.0260
180	10.00	1/4	95	4	200	3.3380	3.3470	0.0090	0.0350
181	10.00	1/4	95	1	250	2.8120	2.8190	0.0070	0.0420
182	10.00	1/4	95	2	250	2.8190	2.8280	0.0090	0.0510
183	10.00	1/4	95	3	250	2.8280	2.8390	0.0110	0.0620
184	10.00	1/4	95	4	250	2.8390	2.8520	0.0130	0.0750
185	10.00	1/4	95	1	300	2.5390	2.5460	0.0070	0.0820
186	10.00	1/4	95	2	300	2.5460	2.5550	0.0090	0.0910
187	10.00	1/4	95	3	300	2.5550	2.5660	0.0110	0.1020
188	10.00	1/4	95	4	300	2.5660	2.5770	0.0110	0.1130
189	10.00	1/4	95	1	350	3.2230	3.2310	0.0080	0.1210
190	10.00	1/4	95	2	350	3.2310	3.2400	0.0090	0.1300
191	10.00	1/4	95	3	350	3.2400	3.2510	0.0110	0.1410
192	10.00	1/4	95	4	350	3.2510	3.2600	0.0090	0.1500
193	10.00	3/8	85	1	200	3.3400	3.3490	0.0090	0.0090
194	10.00	3/8	85	2	200	3.3490	3.3570	0.0080	0.0170
195	10.00	3/8	85	3	200	3.3570	3.3660	0.0090	0.0260
196	10.00	3/8	85	4	200	3.3660	3.3770	0.0110	0.0370
197	10.00	3/8	85	1	250	2.8590	2.8670	0.0080	0.0450
198	10.00	3/8	85	2	250	2.8670	2.8760	0.0090	0.0540
199	10.00	3/8	85	3	250	2.8760	2.8810	0.0050	0.0590
200	10.00	3/8	85	4	250	2.8810	2.8890	0.0080	0.0670
201	10.00	3/8	85	1	300	2.8140	2.8240	0.0100	0.0770
202	10.00	3/8	85	2	300	2.8240	2.8330	0.0090	0.0860
203	10.00	3/8	85	3	300	2.8330	2.8410	0.0080	0.0940
204	10.00	3/8	85	4	300	2.8410	2.8520	0.0110	0.1050
205	10.00	3/8	85	1	350	2.8210	2.8350	0.0140	0.1190
206	10.00	3/8	85	2	350	2.8350	2.8450	0.0100	0.1290
207	10.00	3/8	85	3	350	2.8410	2.8500	0.0090	0.1380
208	10.00	3/8	85	4	350	2.8500	2.8610	0.0110	0.1490
209	10.00	3/8	90	1	200	2.8120	2.8270	0.0150	0.0150
210	10.00	3/8	90	2	200	2.8270	2.8330	0.0060	0.0210
211	10.00	3/8	90	3	200	2.8330	2.8350	0.0020	0.0230
212	10.00	3/8	90	4	200	2.8350	2.8490	0.0140	0.0370
213	10.00	3/8	90	1	250	2.8190	2.8240	0.0050	0.0420
214	10.00	3/8	90	2	250	2.8240	2.8410	0.0170	0.0590
215	10.00	3/8	90	3	250	2.8410	2.8480	0.0070	0.0660
216	10.00	3/8	90	4	250	2.8480	2.8560	0.0080	0.0740
217	10.00	3/8	90	1	300	2.8140	2.8240	0.0100	0.0840
218	10.00	3/8	90	2	300	2.8240	2.8330	0.0090	0.0930
219	10.00	3/8	90	3	300	2.8330	2.8390	0.0060	0.0990
220	10.00	3/8	90	4	300	2.8390	2.8520	0.0130	0.1120
221	10.00	3/8	90	1	350	2.8210	2.8380	0.0170	0.1290
222	10.00	3/8	90	2	350	2.8380	2.8510	0.0130	0.1420
223	10.00	3/8	90	3	350	2.8510	2.8600	0.0090	0.1510
224	10.00	3/8	90	4	350	2.8600	2.8740	0.0140	0.1650
225	10.00	3/8	95	1	200	2.4590	2.4630	0.0040	0.0040
226	10.00	3/8	95	2	200	2.4630	2.4690	0.0060	0.0100
227	10.00	3/8	95	3	200	2.4690	2.4770	0.0080	0.0180
228	10.00	3/8	95	4	200	2.4770	2.4880	0.0110	0.0290
229	10.00	3/8	95	1	250	2.6330	2.6370	0.0040	0.0330
230	10.00	3/8	95	2	250	2.6370	2.6430	0.0060	0.0390
231	10.00	3/8	95	3	250	2.6430	2.6510	0.0080	0.0470
232	10.00	3/8	95	4	250	2.6510	2.6620	0.0110	0.0580
233	10.00	3/8	95	1	300	3.0120	3.0180	0.0060	0.0640
234	10.00	3/8	95	2	300	3.0180	3.0260	0.0080	0.0720
235	10.00	3/8	95	3	300	3.0260	3.0350	0.0090	0.0810
236	10.00	3/8	95	4	300	3.0350	3.0480	0.0130	0.0940

specimen no.	Flow Rate (l/min)	Nozzle Diameter (in.)	Angle	Time (hr.)	Sand Concentration (gm/15 L water)	Final Weight (gm)	Original Weight (gm)	Weight Loss (gm)	Cumulative Weight Loss
237	10.00	3/8	95	1	350	2.8100	2.8160	0.0060	0.1000
238	10.00	3/8	95	2	350	2.8160	2.8230	0.0070	0.1070
239	10.00	3/8	95	3	350	2.8230	2.8340	0.0110	0.1180
240	10.00	3/8	95	4	350	2.8340	2.8460	0.0120	0.1300
241	10.00	1/2	85	1	200	2.6780	2.6850	0.0070	0.0070
242	10.00	1/2	85	2	200	2.6850	2.6910	0.0060	0.0130
243	10.00	1/2	85	3	200	2.6910	2.6950	0.0040	0.0170
244	10.00	1/2	85	4	200	2.6930	2.6990	0.0060	0.0230
245	10.00	1/2	85	1	250	2.7780	2.7810	0.0030	0.0260
246	10.00	1/2	85	2	250	2.7810	2.7830	0.0020	0.0280
247	10.00	1/2	85	3	250	2.7830	2.7850	0.0020	0.0300
248	10.00	1/2	85	4	250	2.8450	2.8900	0.0450	0.0750
249	10.00	1/2	85	1	300	3.1260	3.1290	0.0030	0.0780
250	10.00	1/2	85	2	300	3.1290	3.1330	0.0040	0.0820
251	10.00	1/2	85	3	300	3.1330	3.1370	0.0040	0.0860
252	10.00	1/2	85	4	300	3.1370	3.1420	0.0050	0.0910
253	10.00	1/2	85	1	350	2.7960	2.8010	0.0050	0.0960
254	10.00	1/2	85	2	350	2.8010	2.8090	0.0080	0.1040
255	10.00	1/2	85	3	350	2.8090	2.8120	0.0030	0.1070
256	10.00	1/2	85	4	350	2.8120	2.8128	0.0008	0.1078
257	10.00	1/2	90	1	200	3.2560	3.2600	0.0040	0.0040
258	10.00	1/2	90	2	200	3.2600	3.2650	0.0050	0.0090
259	10.00	1/2	90	3	200	3.2650	3.2720	0.0070	0.0160
260	10.00	1/2	90	4	200	3.2720	3.2850	0.0130	0.0290
261	10.00	1/2	90	1	250	3.1220	3.1270	0.0050	0.0340
262	10.00	1/2	90	2	250	3.1270	3.1340	0.0070	0.0410
263	10.00	1/2	90	3	250	3.1340	3.1480	0.0140	0.0550
264	10.00	1/2	90	4	250	3.1480	3.1660	0.0180	0.0730
265	10.00	1/2	90	1	300	2.7960	2.8010	0.0050	0.0780
266	10.00	1/2	90	2	300	2.8010	2.8090	0.0080	0.0860
267	10.00	1/2	90	3	300	2.8090	2.8230	0.0140	0.1000
268	10.00	1/2	90	4	300	2.8230	2.8390	0.0160	0.1160
269	10.00	1/2	90	1	350	2.8120	2.8190	0.0070	0.1230
270	10.00	1/2	90	2	350	2.8190	2.8280	0.0090	0.1320
271	10.00	1/2	90	3	350	2.8280	2.8410	0.0130	0.1450
272	10.00	1/2	90	4	350	2.8410	2.8570	0.0160	0.1610
273	10.00	1/2	95	1	200	3.2520	3.2550	0.0030	0.0030
274	10.00	1/2	95	2	200	3.2550	3.2590	0.0040	0.0070
275	10.00	1/2	95	3	200	2.2590	2.2610	0.0020	0.0090
276	10.00	1/2	95	4	200	2.2610	2.2650	0.0040	0.0130
277	10.00	1/2	95	1	250	2.7810	2.7840	0.0030	0.0160
278	10.00	1/2	95	2	250	2.7840	2.7860	0.0020	0.0180
279	10.00	1/2	95	3	250	2.7860	2.7890	0.0030	0.0210
280	10.00	1/2	95	4	250	2.7890	2.7910	0.0020	0.0230
281	10.00	1/2	95	1	300	2.7700	2.7720	0.0020	0.0250
282	10.00	1/2	95	2	300	2.7720	2.7730	0.0010	0.0260
283	10.00	1/2	95	3	300	2.7730	2.7770	0.0040	0.0300
284	10.00	1/2	95	4	300	2.7770	2.7800	0.0030	0.0330
285	10.00	1/2	95	1	350	3.1250	3.1290	0.0040	0.0370
286	10.00	1/2	95	2	350	3.1290	3.1350	0.0060	0.0430
287	10.00	1/2	95	3	350	3.1350	3.1370	0.0020	0.0450
288	10.00	1/2	95	4	350	3.1370	3.1390	0.0020	0.0470

Table 5. Test data at flow rate 10 GPM with the addition of chlorine

NOZZLE (inch)	ANGLE	TIME (hr.)	CONCENTRATION	WEIGHT BEFORE	WEIGHT AFTER	DIFFERENCE (gm)
3/8	90	1	200	3.001	3.044	0.043
3/8	90	2	200	3.044	3.067	0.023
3/8	90	3	200	3.067	3.093	0.026
3/8	90	4	200	3.093	3.125	0.032
3/8	90	1	250	3.12	3.138	0.018
3/8	90	2	250	3.138	3.149	0.011
3/8	90	3	250	3.149	3.169	0.02
3/8	90	4	250	3.169	3.199	0.03
3/8	90	1	300	2.954	2.969	0.015
3/8	90	2	300	2.969	2.985	0.016
3/8	90	3	300	2.985	3.008	0.023
3/8	90	4	300	3.008	3.041	0.033
3/8	90	1	350	3.011	3.021	0.01
3/8	90	2	350	3.021	3.045	0.024
3/8	90	3	350	3.045	3.072	0.027
3/8	90	4	350	3.072	3.119	0.047

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