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Breaking Good

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Contents

Abstract

This technical document outlines the design and development of a water-based erosion testing device tailored for applications within the nuclear engineering sector. The system aims to provide a comprehensive platform for studying erosion phenomena in materials. Emphasizing versatility and functionality, the document explores various system architectures, including closed water loop systems and tumbler configurations. Additionally, a range of subsystems is proposed to enhance testing capabilities, such as slurry mixing chambers, pressure monitoring systems, and precise dispensing mechanisms. Through this approach, the document seeks to offer innovative solutions for conducting erosion testing in a controlled environment, empowering nuclear engineering professionals with valuable insights into material durability and performance under erosive conditions.

Solution 1: tumbler-system

Schematic of Tumber-system

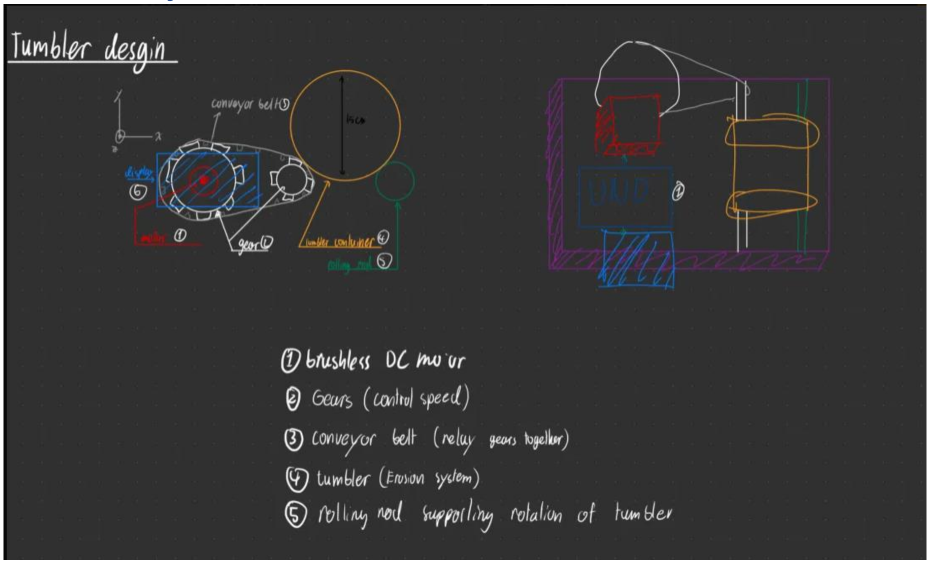
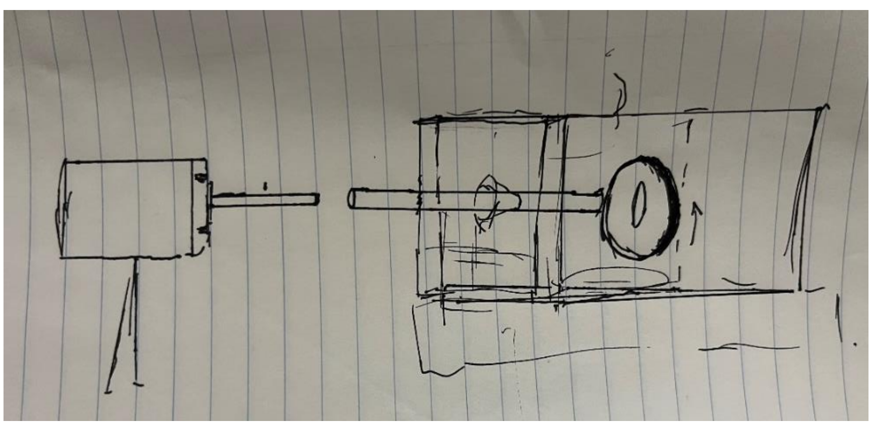


Figure 1: sketch of tumbler system

The Tumbler-System takes inspiration from a rock tumbling device used to smoothen rocks. This system will be used to accelerate the rate of erosion of a sample by tumbling it with abrasive liquids. The tumbling container subsystem (4) capsule isn't connected to the spinning subsystem (1,2,3,5). This is done to make liquid solution (slurry) change and sample introduction easier for the device.

Solution 2: spinner-system

Picture:



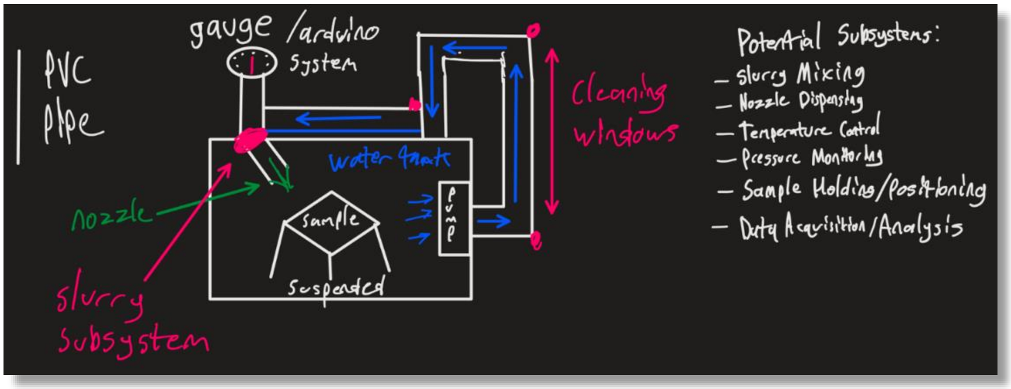
Description:

As the name suggests, this system spins the test sample through an erosive-resistant hollow cylinder that is connected to the external motor through a slider mate, the test sample is attached to the hollow cylinder in the same manner and is fully (or partially) submerged in the slurry fluid contained in a 12″ x 6″ x 8″ (2.5-gallon volume) rectangular tank made from PC plastic. An external support can be attached to the motor (or container) for height adjustment. The overall system is made watertight by using Rotary Shaft Seals. The system is uncomplicated in structure (made up of four main components), costs little to build, and can test variables including (velocity, number of abrasives and material/component durability) under a controlled environment. However, the system may be inefficient as the abrasives will be concentrated on the bottom if there is insufficient rpm, thus causing less impact on the test sample and resulting in a longer experiment time. Possible fixes could include an extra subsystem with a bottom attached propeller that allows for extra liquid flow and exchange.

Solution 3 : SNP-System

Title: Slurry, Nozzle, Pump System

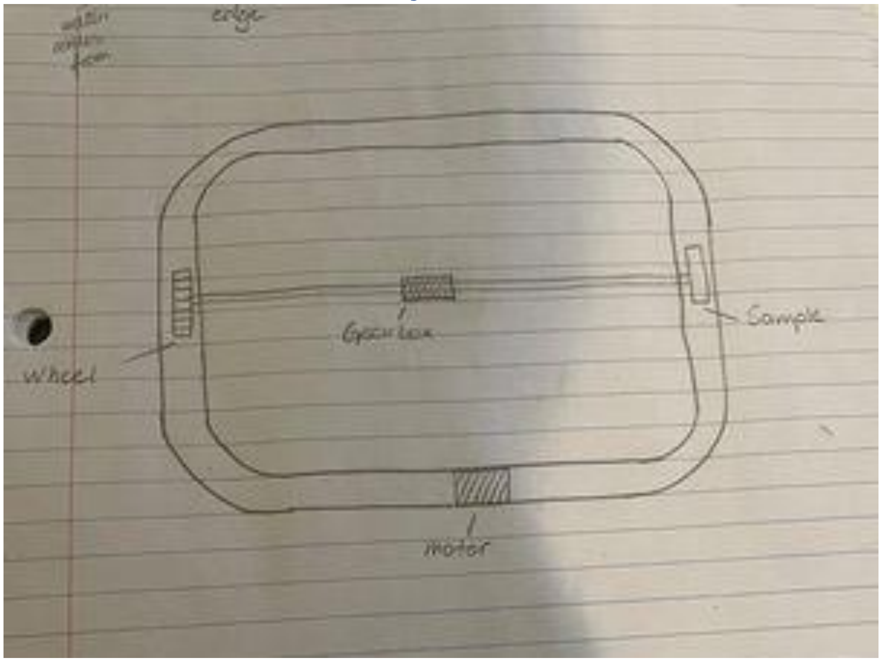
Picture



Description:

Our water-based erosion testing system integrates a slurry mixing chamber with a precision pump mechanism to simulate erosive conditions accurately. The system begins with a mixing chamber where abrasive particles are suspended in a carrier fluid to replicate erosion-inducing media. A specialized pump system then delivers this slurry to a dispensing nozzle positioned above the test sample, allowing for precise control over flow rates. This configuration enables the replication of various erosion scenarios, making it suitable for a wide range of material testing applications. By combining slurry dispersion with pump control, our system provides a versatile platform for studying erosion phenomena in diverse settings.

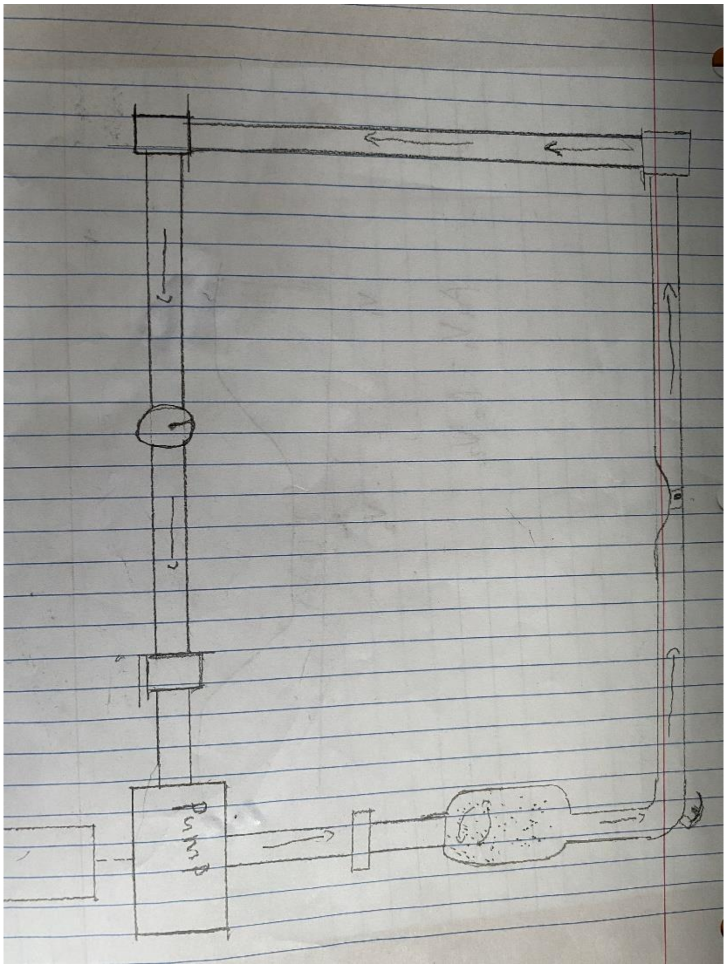
Solution 4: Watermill System



Description:

This system takes inspiration from the old watermill designs used to generate hydroelectric power. This system is particularly designed to have as little parts as possible and let the fluid itself do the work. Using a cog like wheel with notches to use the water current to spin the wheel, a rod is attached to the wheel and the sample on the other side of the rod to spin the sample. The sample, however, will not spin well if going against the water current so a gearbox is added in the center to change the direction in which the sample will spin. A DC motor is also used near the center area allowing for the water flow to stay consistent and fast ensuring that the sample is eroding. The corners are also curved rather than being 90 degree turns allowing for the water flow to stay at higher speeds and overall keeping the water flow steady.

Solution 5: Circle pipe



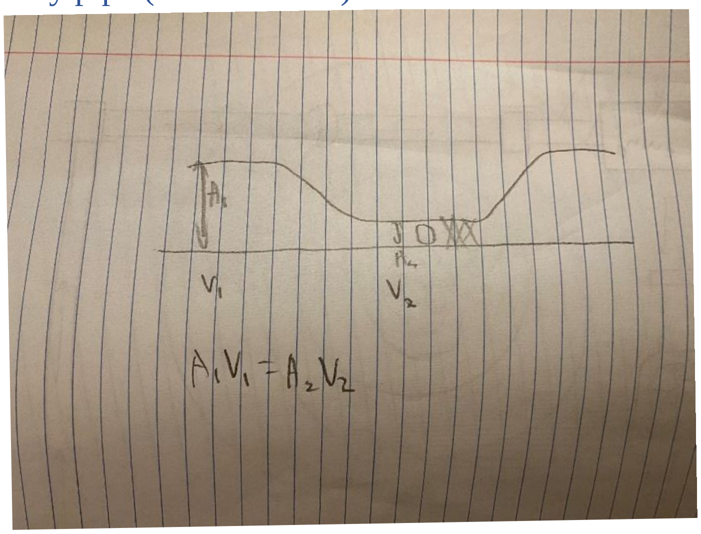
Subsystems

- Continuity pipe
- Safety Pipe Cleaner
- Simple Slurry Stirrer

It is a closed loop system that is a loop of pipes with water flowing through them. In the loop there is a slurry mixer pump pressure gauge and sample holder. The main idea is that the pump will push water through the pipes at a high pressure, which is ministered with a pressure gauge, to make sure the pipe does not rupture which has the potential to be dangerous. The water in the pipe is mixed with some sort of minerals like sand so that the particles that flow around the system are larger. Thus, impacting the sample with more force (because force is directly proportional to mass). Then the slurry mixture is funneled into a smaller part of the pipe so that the velocity increases (due to continuity A1V1=A2V2), which will increase the force of impact of the particles. There is also a valve on the top right corner of the loop system which can be used for changing the slurry mixture in the pipe. If possible, the pump will be attached to an Arduino giving it commands of how hard it will pump the water through the system.

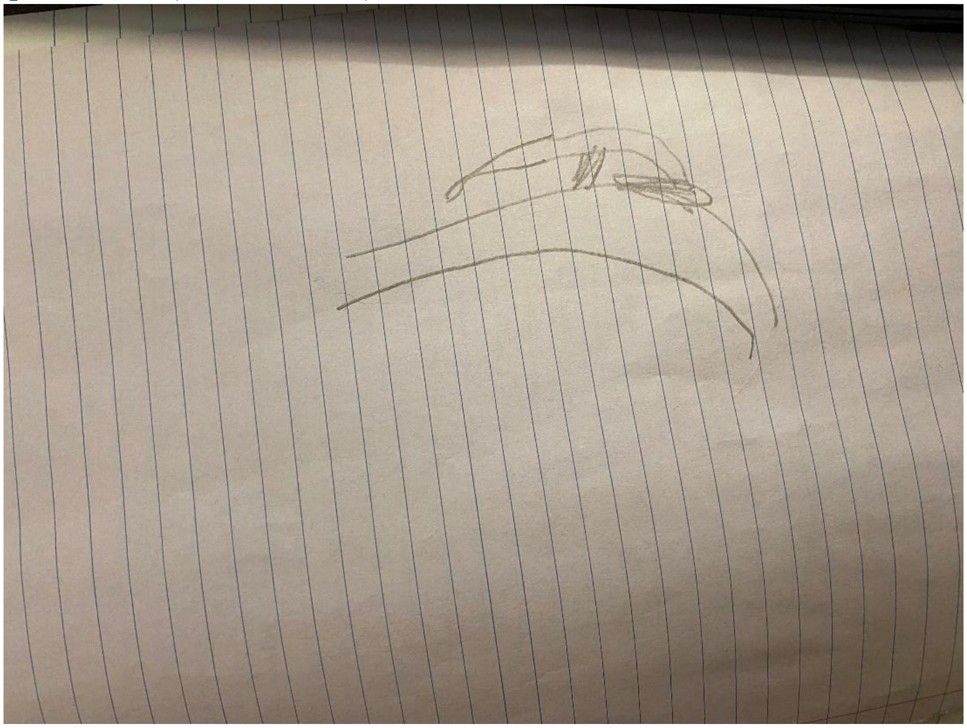
All subsystems

Continuity pipe (James Clarke)



The continuity pipe utilizes a concept that builds off Bernoulli's principle. That P1+1/2pv^2 +pgh=constant. Because this is constant the velocity multiplied by the cross-sectional area of one part of the pipe will equal the volume multiplied by the cross-sectional area of the second part. So, if the cross-sectional area of the pipe decreases the velocity will increase. Because velocity is directly proportional to the force of a particle's impact onto the substance. Decreasing the cross-sectional area will increase the erosion of the sample. If a machine cannot test withing the accepted range given by the design criteria (within hours) then this can speed up the process.

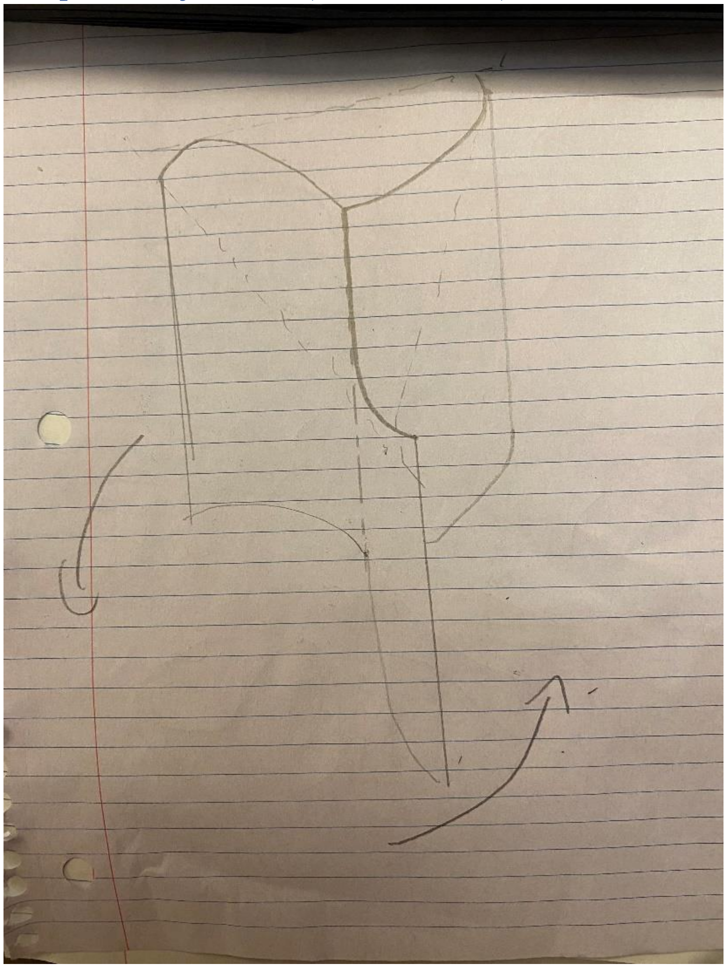
Safety Pipe Cleaner (James Clarke)



The cleaning valve is a subsystem that was originally built to find a way to clean the insides of the machine by unsealing whole on the side of it releasing the water. Although this subsystem can also be calibrated so that it cannot withstand a dangerous amount of pressure, which can happen because nature naturally will work to increase enthalpy (chaos) in a system. So, if a certain burst of dangerously high pressure goes through the system which comes close to the compressive forces of the pipes it can break and squirt out in a safe direction. This is on the border of violating the Criteria that it must be waterproof because to have the safety measure in the first case indicates that the machine has a risk of giving into the pressure of the water but it's only a safety measure so I doubt this function for the valve will be used often for a functional device.

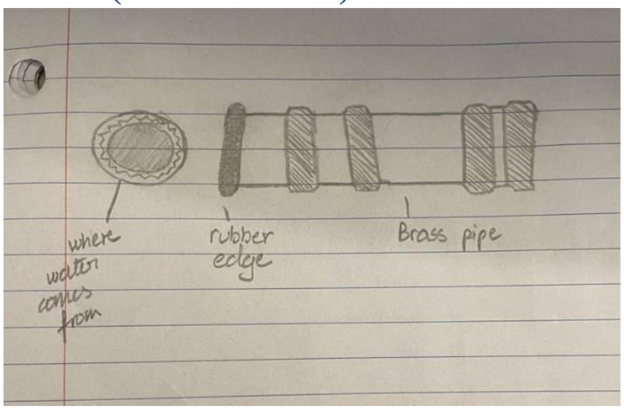
A side note is that with more development of this subsystem it could be used as a potential “stop button” of the device so that the machine stops right after pulling this valve which is also part of the design criteria.

Simple Slurry Stirrer (James Clarke)



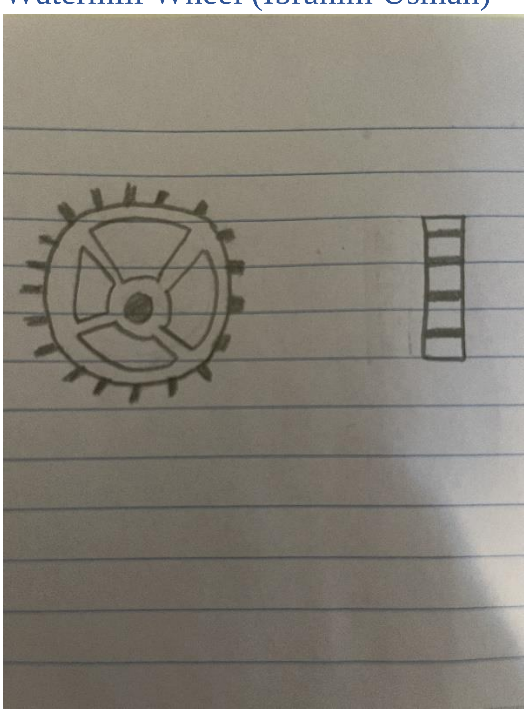
The slurry mixer device does not need to be accurate, the only requirement for it is that it does not go too fast so that it degrades the particles. So, the idea of the simple slurry stirrer is like a propeller if the propeller is much thicker than usual so that the pressure will push the propeller in a circular movement to mix the sand with the water. The image above is what the simple slurry stirrer is meant to loop except the bottom of it is meant to be rotated, like if you twisted it in the directions of the arrows. This subsystem takes away a bit of pressure from the device, but it works without any use of electricity which is why it's called the Simple Slurry Stirrer.

Nozzle (Ibrahim Usman)



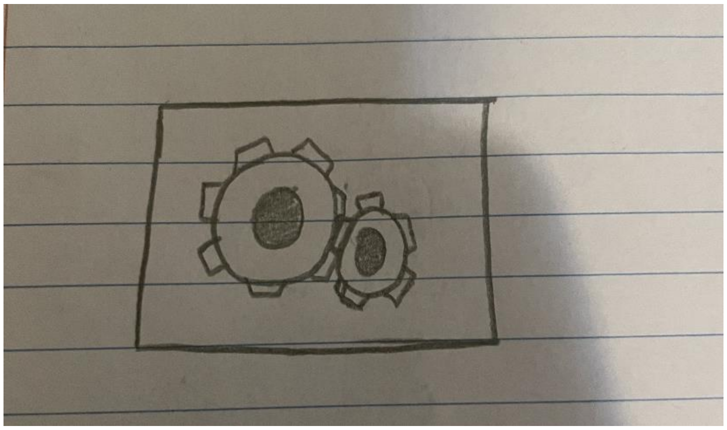
The nozzle is a subsystem designed for a jet-based erosion testing system. The purpose of the nozzle is to compress the fluid being used in the erosion system and spray it on the sample. This is effective as the fluid contacting the sample at a high rate of speed simulates the erosion at a much faster pace. The fluid pressure is increased by using Bernoulli's principle where p1+pgh1=p2+pgh2. The nozzle will also shoot the fluid at around a width of 3 inches. This ensures full coverage of the sample and even erosion to be applied on the sample. The nozzle will be 1 inch wide.

Watermill Wheel (Ibrahim Usman)



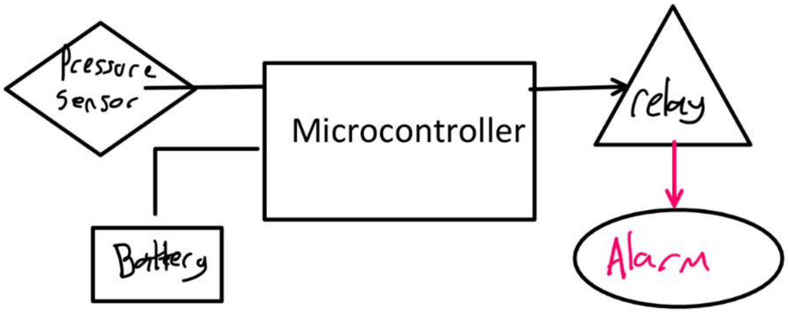
The watermill wheel works by having notches that are on the outer edge which causes the water to hit those notches and push the watermill wheel in that direction. The metal rod is attached to the center causing the rod to spin alongside the wheel. This design depends on the water flow speed for efficiency and can be increased or decreased using a motor that would increase or decrease water speed.

Gearbox (Ibrahim Usman)



The gearbox allows for the direction in which the sample is spinning to be changed. This allows for the sample in the watermill design to spin in the same direction as the water current and keep the sample spinning fast. The gearbox can also be used to increase the rpm for the sample which though is not the main way of testing erosion, it helps with the sample being eroded faster.

Pressure Monitoring Sub-system (Ahsan Shaikh)



Our pressure monitoring subsystem enhances the functionality of the erosion testing device by providing real-time monitoring and control of slurry pressure during testing. At its core, the subsystem features a high-precision pressure sensor that continuously measures the pressure exerted by the slurry as it is dispensed onto the test sample. This sensor is seamlessly integrated with a microcontroller unit, which processes the pressure data and communicates with a battery-powered alarm system. In the event of pressure fluctuations exceeding predefined thresholds, the alarm alerts operators, signaling potential issues such as clogging or system malfunctions. Additionally, a relay mechanism can be incorporated to trigger automated responses, such as pausing the testing process or adjusting pump settings to mitigate pressure spikes. By incorporating this sophisticated monitoring subsystem, our erosion testing device ensures optimal testing conditions and enhances the safety and reliability of experimental procedures.

Spinning Subsystem (refer to figure 1) (Lightning)

The Spinning subsystem utilizes these components:

- 2x gears, Ratio of 3/1
- 1x conveyor belt
- 1x brushless DC motor
- 1x Arduino uno

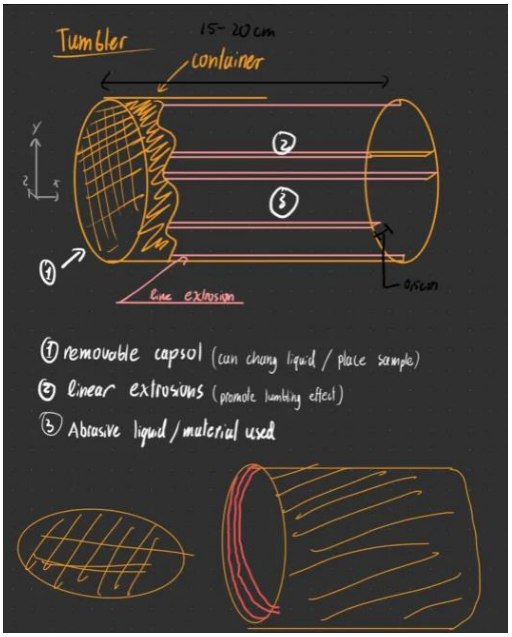
A D.C motor, controlled by the Arduino, turns a large gear that's connected by a conveyor belt to the spinning gear. The spinning gear and the belt are the elements that are responsible for spinning the tumbler system at a higher revolution. This is achieved by utilizing different sized gears to obtain a faster spinning speed. The spinning tumbler will also be supported by an additional spinning rod located behind the capsule.

The large gear will have a diameter of 9-10cm, and the smaller gear will have a diameter of 3cm. Both gears will be located 10-12 cm apart from each other. The spinning rod will be located 10 cm apart from the small gear.

This subsystem isn't expensive and provides a simple solution to increase the speed of erosion. The subsystem is moderately safe with no sharp edges. The gear and conveyor belt will be covered along the sides to prevent any hazardous accidents.

T.C subsystem (Tumbling Container subsystem) (Lightning)

Figure 2



The tumbling system utilizes these components:

- 1x 15cm diameter by 15-20cm length metallic capsule,
- 5x 0.5cm by 15-20 cm sheets, material to be determined.
- 1x screw on cover

The T.C system would spin the whole system. Unlike conventional ideas where the sample would be set in a fixed position and have the liquid put in motion, or vice versa. The sample and the slurry would be moving and tumbling in this system.

The capsule-like build allows the user to efficiently utilize different liquid solutions without much trouble. The Screw on cover will be airtight. This design doesn't require the user to put the sample in any specific position, thus making it easy to use. User simply puts the sample along with the liquid before starting the spin. Blunt linear extrusions are installed inside the capsule to promote mixing and tumbling for a more accelerated result.

Experiment set up

Explain how experiments will be conducted using your device:

Using the most popular ideas of devices in our group how the erosion force will be measured is by measuring the substances weight before putting it into the device for several hours and afterwards. Then the change in mass of the object will be equal to the amount of erosion. Although in case we cannot measure any difference in mass, then photographic evidence will be used, by making before and after pictures of the samples and comparing them. Pretty much the sample will be put in a machine that will erode it then the sample will be compared to its state before after.

Sample preparation.

Ordered samples will be put into the respective size described by our design criteria. And if needed will be sanded to make sure that the surface is smooth so if erosion occurs a change will be visible.

Conclusion

The tumbler's advantage is its increase in abrasion when tumbling, its simple concept, and its ease to use. However, this design has flaws such as the fact that the liquid might have to be replaced after each test, this system does not simulate the environment used by the CNL.

The downside of the SNP machine is that the slurry mixture can cause the nozzle to get clogged up which would lower the efficiency and the pressure of the slurry being exerted out of the nozzle and pumping the slurry mixture 90 degrees up would require a really strong pump which would be expensive to buy and maintain. The advantages of SNP system is that it does not waste water because it is in a loop system, this helps the cost of working the machine. Its speed is also another superior quality of the machine because it will be able to blow pressurized water out onto the sample which will be able to erode the sample much faster than other designs like the tumbler design.

The spinner's advantage is its ease to assemble and maintain at a low cost, however, this design results in a low abrasive impact on the surface area of the testing sample. We ultimately chose this design because it is quick to implement and has the ability to simulate/ test multiple variables under similar conditions to real life, which our other samples do not possess.